# PETROLOGY OF THE PURCELL SILLS IN THE ST. MARY LAKE AREA, B. C.

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# PETROLOGY OF THE PURCELL SILLS IN THE ST. MARY LAKE AREA, BRITISH COLUMBIA

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ABSTRACT

The Purcell Sills of the St. Mary Lake area, British Columbia, have mineral compositions and textures which can be related to deuteric alteration and autometamorphism of quartz diabase. Amphibolization, saussuritization and granophyric intergrowths reflect the different cooling histories of the various sills, which in turn are related to the depth of intrusion and thickness of the sills.

On the basis of potassium-argon age determinations, which gave 600 and 620 million years as the ages of the emplacement of the Purcell intrusions, it is concluded that the Purcell Sills of southeastern British Columbia are late Precambrian in age.

## ACKNOWLEDGEMENTS

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# CHAPTER I

# INTRODUCTION

## GENERAL STATEMENT

Exposed in the Purcell mountains on either side of St. Mary Lake in southeastern British Columbia is a thick succession of late Precambrian sedimentary formations. Within these sedimentary rocks occur numerous tabular bodies of basic igneous rock, known as the Purcell Intrusives. The intrusives are most abundant and thickest within the Aldridge formation, the oldest sedimentary beds exposed in the Purcell Range. Although many of the Purcell intrusives cut their enclosing sedimentary beds, concordance is the rule. Since all of the bodies sampled for this study were concordant, the term Purcell sills was adopted in the title.

The sills are composed of a medium-grained quartz diabase, with subhedral laths of plagioclase feldspar and green amphiboles showing relict diabasic texture. Intergrowths of quartz and feldspar occur either at the contacts of the sills from assimilated material, or within the sill as an acid differentiate.

Sills which have been similarly described occur within the Purcell Mountains, eastward into the Waterton Park area of Alberta, and southward to central Idaho and west-central Montana.

A study of the Purcell sills seemed justified at this time for a number of reasons:

(1) Considerable work has been done on the Purcell intrusives, including the investigations of Daly (1912), Schofield (1915), Jure (1929), Hume (1932), Rice (1941), Swanson and Gunning (1949),

Leech (1952), Reesor (1953), Douglas (1953), and Scott (1954). However, few comparative studies have been made between sills from different areas within the Purcell terrain.

(2) Maps on a scale of one mile to one inch recently published by the Geological Survey of Canada show in detail the distribution of the sills, thus facilitating field work.

(3) The recently developed potassium-argon dating technique offered a possibility of dating the intrusion of the sills, using the biotite hornfels developed at the contacts of the sills.

(4) The Proterozoic Purcell trough was filled with a large volume of sediments, apparently derived from an eastern source. More recently the uplifted Purcell strata have contributed material to the Cretaceous and later sedimentary formations of Alberta. The Purcell sedimentary sequence is thus of interest in relation to two widely separated periods in the geologic history of Alberta.

In the spring and fall seasons, 1957, a detailed sampling was made of a sill exposed on Resort Creek, immediately north of St. Mary Lake. Samples were obtained for comparative purposes from five other sills in southeastern British Columbia and adjacent Alberta.

# CHAPTER II

## THE BELTIAN GEOSYNCLINE

In the area between Idaho and central British Columbia a thick succession of argillites, quartzites, and limestones was laid down over a long period in the late Precambrian. This system of rocks forms the Beltian of Walcott. The Purcell intrusives, and all diabase and gabbro sills which have been correlated with them, occur in formations of the Beltian system. The distribution of the Beltian terrain thus limits the occurrence of the Purcell intrusives.

The main axis of the geosyncline or the greatest thickness of Beltian rocks extends from the Findlay Creek, British Columbia, map area (45,000 feet; Reesor, 1957) to Missoula, Montana (50,000 feet; Clapp, 1932). The formations grade into each other with no suggestion of a break and possess similar lithologies. Generally, the rocks are very fine grained, with the lower part of the Beltian consisting of argillaceous quartzites and argillites, and the upper part similar but becoming more calcareous. They are shallow water deposits as seen by mud cracks, ripple marks and cross bedding.

The sediments in this geosyncline were apparently derived from the mature weathering of an Archean terrain of low relief. The conditions of deposition were perhaps similar to those in the Gulf Coast geosyncline at the present time, where sedimentation and subsidence of the basin are in balance.

## THE BELTIAN TERRAIN IN CANADA

Our knowledge of the geology of southeastern British Columbia is based mainly on work done by the Geological Survey of Canada.

G.M. Dawson (1885) explored a portion of the interior region of southern British Columbia between latitudes 49° and 51° N. He gave the name "Purcell Range" to all the mountains between Kootenay Lake and the Rocky Mountain Trench.

R.A. Daly (1904) used the term Purcell Series for the thick sequence of sedimentary rocks of the Purcell Range. He divided the series into formations, with type localities mainly along the International Boundary.

S.J. Schofield (1915) studied the relation of the Purcell Series to the overlying Cambrian and placed the age of the Purcell as Precambrian.

J.F. Walker (1926) divided the Purcell Series into lower and upper parts, designating the Purcell lava as the top of the Lower Purcell. In the Windermere area he named the rocks overlying the Upper Purcell, but underlying the Paleozoic strata, the Windermere Series.

H.M.A. Rice (1937, 1941) gave the total thickness of the Purcell Series as 45,000 feet. This figure includes the basal Ft. Steele formation, found only in the Cranbrook map area.

G.B. Leech (1954, 1957), in mapping the St. Mary Lake area, divided the Aldridge formation into three divisions. The

Purcell sills were shown to be most numerous in the lower and middle members of the Aldridge formation.

J.E. Reesor (1957) gave an excellent review of the current knowledge of the Proterozoic of southeastern British Columbia and southwestern Alberta. He presented a correlation of stratigraphic successions and formation names for the areas which have been studied.

## Purcell Series

An outline of the Precambrian stratigraphy of the central and eastern Purcell range, given by J.E. Reesor (1957), is as follows:

| | | |
|---|---|---|
| Upper Purcell | Mt. Nelson formation | 3,400'+ |
| | Dutch Creek formation | 3,500' |
| - - - - - - | - - - - - - | - - - - - - |
| | Purcell lava | |
| | Siyeh formation | 2,800' |
| Lower Purcell | Kitchener formation | 5,000' |
| | Creston formation | 6,300' |
| | Aldridge formation | 15,000' |
| | Ft. Steele formation | 6,000' |
| | base not exposed | |

The Purcell Series is described as follows:

Ft. Steele formation - quartzite, argillaceous quartzite, grey quartzite, dolomitic argillite. This formation has not been found exposed west of the Rocky Mountain Trench.

| | | |
|---|---|---|
| Aldridge formation | - | massive and laminated black argillite, very fine grained quartzite, rusty weathering. |
| Creston formation | - | fine grained quartzite or argillite, green or grey weathering. |
| Kitchener formation | - | variously-colored, calcareous and dolomitic argillite. |
| Siyeh formation | - | argillite and argillaceous quartzite. |
| Purcell lava | - | dark green to black, amygdaloidal scoriaceous basalt. |
| Dutch Creek formation | - | conglomerate, siliceous limestone, sandy argillite with abundant casts of salt crystals in Cranbrook area. |
| Mt. Nelson formation | - | massive dolomitic limestone in the Windermere area. A good marker horizon of white quartzite is found at the base of the formation. |

The outline above is a composite section, based on thicknesses given by Rice (1937, 1941) for the lower part, and by Walker (1926) for the upper part.

The northern limit of the exposed Purcell Series is near latitude $50^\circ$ 30' and longitude $116^\circ$. The upper Purcell strata form a north plunging geanticline and disappear beneath the younger Windermere Series. The Windermere rocks in turn plunge northward beneath lower Paleozoic strata. Rocks that may be correlated with the Windermere appear further north at the surface within the Big Bend of the Columbia River (Gunning, 1929).

## Windermere Series

Originally defined by Walker (1926) the Windermere comprises the Toby conglomerate, Irene volcanics and the Horsethief Creek formation, lying unconformably on the Upper Purcell strata.

An outline of the Windermere Series in the Windermere area is as follows:

| | | | |
|---|---|---|---|
| Windermere Series | Horsethief Creek formation | 5,000' | fine grained clastics. |
| | Irene volcanics | | andesitic greenstones. |
| | Toby conglomerate | 50 to 2,000' | conglomerate. |

unconformity

## Lewis Series

Proterozoic rocks in the Waterton area near the International Boundary are known as the Lewis Series. The Lewis Series is comparable to the Purcell Series but is thinner (Reesor, 1957). Douglas (1953) gives a thickness of 11,000 feet for the section at Waterton, Alberta. A widespread lava flow occurs everywhere at, or near the same horizon (Reesor, 1957) and serves as a means of correlation of these thick unfossiliferous successions.

An outline of the Proterozoic stratigraphy at Waterton, given by Douglas (1953), is as follows:

| | | | |
|---|---|---|---|
| Lewis Series | Kintla formation | eroded 2900'+ | argillite |
| | Sheppard formation | 600' | siliceous dolomite |
| | Purcell lava | 260' | altered basalt |
| | Siyeh formation | 3000' | limestone |

| | | |
|---|---|---|
| Grinnell formation | 750' | argillite & quartzite |
| Appekuny formation | 1100' | meta argillite |
| Altyn formation | 500' | siliceous dolomite |
| Waterton formation | 617' | siliceous dolomite |

base not exposed

## THE BELTIAN TERRAIN IN THE UNITED STATES

The Beltian rocks have been mapped as a more or less continuous lithologic assemblage from the International Boundary to southeastern Idaho. The southern limit of the Beltian rocks is near latitude $44^{\circ}$ 30' and longitude $113^{\circ}$ 30', approximately 30 miles south of Lemhi, Idaho.

G.W. Berry (1943) stated that no Beltian rocks are found to the south in Tobacco Root, Madison and Gallatin Ranges. He confirmed Peales (1885) suggestion of a shore line with the presence of a Beltian conglomerate lying unconformably upon the Archean Pony Series.

At Jefferson Canyon, Montana, conglomerates with gneissic boulders 18" across consisting of unweathered feldspar prove that the shore line was close. Deiss (1935) considered the surface at Jefferson Canyon a peneplane resulting from a tremendous amount of erosion prior to the invasion of the Cambrian sea. He believed that the Beltian was originally present over the entire area but was locally removed. A uniform thickness of the Cambrian Flathead sandstone throughout the area indicates a nearly level surface.

R. Scholten (1957) states that there are no Beltian rocks exposed east of the Tendoy Range in the Lima region of southwest Montana and adjacent Idaho. He concludes it is either a non-depositional or an erosional edge phenomenon.

The concept of an east-west trending shoreline with no Beltian deposition to the south of latitude 44° 30' and the pre-Beltian basement peneplaned to produce 40,000 feet of Beltian rock to the north, appears best to fit the field evidence.

# CHAPTER III

## DISTRIBUTION OF PURCELL INTRUSIVES

The dominant mode of occurrence of the Purcell intrusives is as sills. Dykes are relatively minor in terms of total volume of intruded rock. The sills are most numerous and thickest in the lowest formations of the Beltian system. In the St. Mary Lake area, and west of Kingsgate, the thickest sills are in the Aldridge formation. The uniform thickness of the sills suggests that they were emplaced between horizontal or gently-dipping beds. Evidence of thickening of the sills at the crests of folds is lacking. The sills were later tilted and deformed into their present position along with the enclosing strata. The exposure of the igneous bodies has become possible through extensive block faulting and upturning, followed by erosion.

Granite stocks of Cretaceous age, satellitic to the Nelson batholith, occur in the St. Mary Lake and Cranbrook map area adjacent to the St. Mary fault. In the Dewar Creek map area the White Creek batholith has distorted the pattern of sill outcrop by sharply deflecting the regional strike of the Aldridge formation.

The main characteristics of intrusive diabasic sills are their occurrence over vast areas and their uniform thickness for distances of many miles along strike.

Pardee (1911), in the St. Joe River region, Idaho, named the Wishard Sill where it was traced for many miles.

Kirkham (1926) traced a sill in the Boundary County, Idaho, for thirty-four miles before it was terminated by faulting.

Anderson (1930), in the Clark Fork District, Idaho, traced a sill for twenty-one miles along the crest of the Cabinet Range.

Gabbroic or diabasic sills within Proterozoic strata have been reported and mapped in many localities in southeastern British Columbia and adjacent Alberta. The following may be considered to be the main occurrences (see Fig. 1):

1. St. Mary Lake, British Columbia; Leech (1957)
2. Findlay Creek, British Columbia; Reesor (1953a)
3. Dewar Creek, British Columbia; Reesor (1953b)
4. Cranbrook, British Columbia; Schofield (1915), Rice (1935, 1941)
5. Kingsgate, British Columbia; Daly (1912)
6. Waterton Lake, Alberta; Douglas (1953).

In the northwestern United States similar sills have been reported from the following localities:

1. Boundary County, Idaho; Kirkham (1926)
2. Clark Fork District, Idaho; Anderson (1930)
3. Libby Quadrangle, Montana; Gibson, Jenks (1948)
4. Canyon Ferry, Montana; Mertie (1951)
5. Northwest Montana; Clapp (1932)
6. Glacier Park, Montana; Dyson (1949).

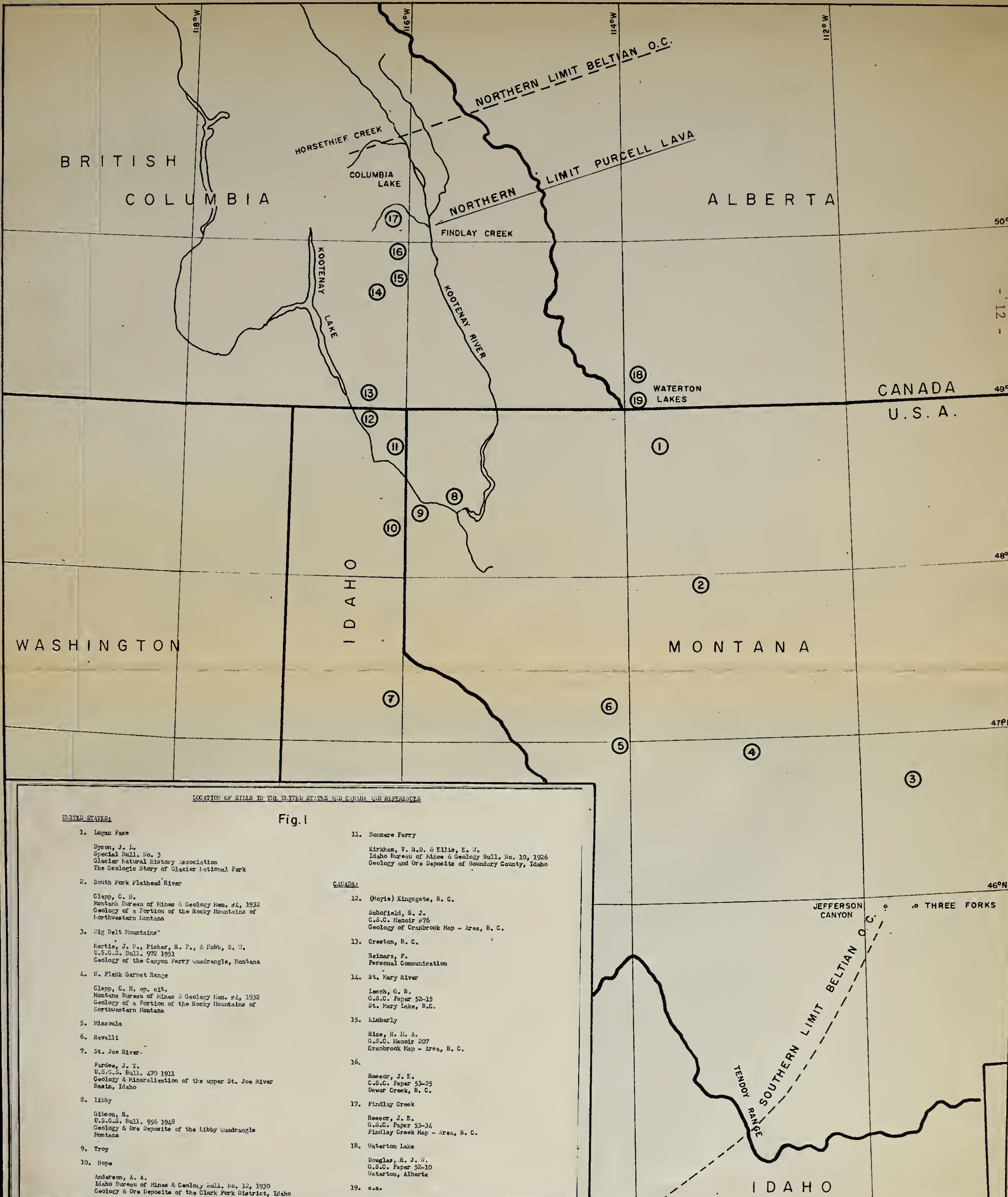



Fig. I

LOCATION OF SILLS IN THE UNITED STATES AND CANADA AND REFERENCES

UNITED STATES:

1. Logan Pass

Dyson, J. L.
Special Bull. No. 3
Glacier Natural History Association
The Geologic Story of Glacier National Park

2. South Fork Flathead River

Clapp, C. H.
Montana Bureau of Mines & Geology Mem. #4, 1932
Geology of a Portion of the Rocky Mountains of Northwestern Montana

3. Big Belt Mountains

Mertie, J. B., Fisher, R. P., & Hobb, S. W.
U.S.G.S. Bull. 972 1951
Geology of the Canyon Ferry Quadrangle, Montana

4. N. Flank Garnet Range

Clapp, C. H. op. cit.
Montana Bureau of Mines & Geology Mem. #4, 1932
Geology of a Portion of the Rocky Mountains of Northwestern Montana

5. Missoula

6. Ravalli

7. St. Joe River

Pardee, J. T.
U.S.G.S. Bull. 470 1911
Geology & Mineralization of the upper St. Joe River Basin, Idaho

8. Libby

Gibson, R.
U.S.G.S. Bull. 956 1948
Geology & Ore Deposits of the Libby Quadrangle Montana

9. Troy

10. Hope

Anderson, A. A.
Idaho Bureau of Mines & Geology Bull. No. 12, 1930
Geology & Ore Deposits of the Clark Fork District, Idaho

11. Bonners Ferry

Kirkham, V. R.D. & Ellis, E. W.
Idaho Bureau of Mines & Geology Bull. No. 10, 1926
Geology and Ore Deposits of Boundary County, Idaho

CANADA:

12. (Moyie) Kingsgate, B. C.

Schofield, S. J.
C.S.C. Memoir #76
Geology of Cranbrook Map - Area, B. C.

13. Creston, B. C.

Reinarz, F.
Personal Communication

14. St. Mary River

Leech, G. B.
G.S.C. Paper 52-15
St. Mary Lake, B.C.

15. Kimberly

Rice, H. M. A.
G.S.C. Memoir 207
Cranbrook Map - Area, B. C.

16.

Reesor, J. E.
C.S.C. Paper 53-25
Dewar Creek, B. C.

17. Findlay Creek

Reesor, J. E.
G.S.C. Paper 53-34
Findlay Creek Map - Area, B. C.

18. Waterton Lake

Douglas, R. J. W.
G.S.C. Paper 52-10
Waterton, Alberta

19. a.a.

# CHAPTER IV

## PETROGRAPHY

### FIELD WORK

During the summer of 1957 the writer visited the Purcell sills at St. Mary Lake and Kingsgate, British Columbia, and Waterton Park, Alberta. Samples were collected stratigraphically from these locations and were called the Resort Creek, Moyie, and Blakiston Brook sections respectively (for locations see Figure 3).

1. Resort Creek Section.

Resort Creek is a small stream which flows down the south face of Bootleg Mountain to St. Mary Lake near its east end.

The section is taken across the south face of the upper "A" sill, sampling from north to south along Resort Creek (Schofield, 1915, p. 74).

Sill "A" stratigraphically is the highest sill of a series of five sills and is approximately 200 feet thick, although the base was not exposed. A very sharp contact was seen between the upper margin of the sill and the Aldridge quartzites.

A biotite hornfels extends at least 15 feet above the upper contact of the sill with the sediments. This baked sediment resembles a light grey, fine grained, biotite granite.

2. Moyie Section.

The sill sampled is exposed on the eastern slope of the ridge west of Kingsgate, British Columbia, on the International Boundary line.

The direction of sampling was from east to west on the upper "A" sill (Schofield, 1915, p. 72).

A very sharp contact separates the dark green sill to the east and a light grey baked sediment to the west. This baked sediment near the contact looks like a light grey, medium-grained granite.

3. Blakiston Brook Section.

A dark green, badly-fractured sill is exposed intruding the Grinnell formation near Blakiston Brook on the road to Red Rock Canyon in Waterton Park, Alberta (Douglas, 1953).

Samples were collected stratigraphically across the sill from south to north. The sill is 50 feet thick and strikes in an easterly direction.

The contact was very sharp between the sill and the banded red argillites and quartzites. A very fine-grained, light green, cherty-looking rock a few inches wide, forms the contact rock.

Dr. T. Patching, in 1955, collected samples of a sill about 100 feet thick intruding the Siyeh formation at Lake Alderson, Waterton Park, Alberta.

Dr. R.E. Folinsbee, during 1957, collected a sample from a southward extension of the Lake Alderson sill, at Logan Pass, Glacier Park, Montana.

Dr. R.A. Burwash collected a sample from the Kimberley intrusive, east of the Sullivan mine, Kimberley, British Columbia.

## LABORATORY STUDIES

A study of thin sections from the following localities was carried out in the winter of 1957-58:

| | | |
|---|---|---|
| 1. | Resort Creek Section | 13 thin sections |
| 2. | St. Mary Lake "B" sill | 1 thin section |
| 3. | Kimberley Intrusive | 1 thin section |
| 4. | Moyie Section | 6 thin sections |
| 5. | Blakiston Brook Section | 6 thin sections |
| 6. | Lake Alderson Section | 5 thin sections |
| 7. | Logan Pass | 1 thin section |

Detailed descriptions of the thin sections are given in the Appendix.

In this chapter the general features of the sills will be considered, starting with those in the St. Mary Lake area, from which the greatest number of samples were collected. The petrology of two sills in the Waterton Lake area will be discussed in the next chapter.

Three samples of biotite from the contact phase of the Purcell sills were prepared and forwarded to Dr. H. Baadsgaard at the University of Alberta for age determinations by the potassium-argon method. The results of this work will be given in Chapter VII.

### ST. MARY LAKE AREA, BRITISH COLUMBIA

The Purcell sills which intrude the Aldridge formation at St. Mary Lake are quartz diabase. The names Moyie Sills and Purcell

Intrusives have been applied to these sills by previous investigators, who considered them to be metadiorites or hornblende gabbros.

In this locality Schofield (1915) studied five sills which he called "A", "B", "C", "D", "E" from top to bottom respectively. They are located due north of St. Mary Lake, striking in a northerly direction and dipping approximately twenty degrees to the west. Sills "B", "D", and "E" are over 500 feet thick and sills "A" and "C" are somewhat less.

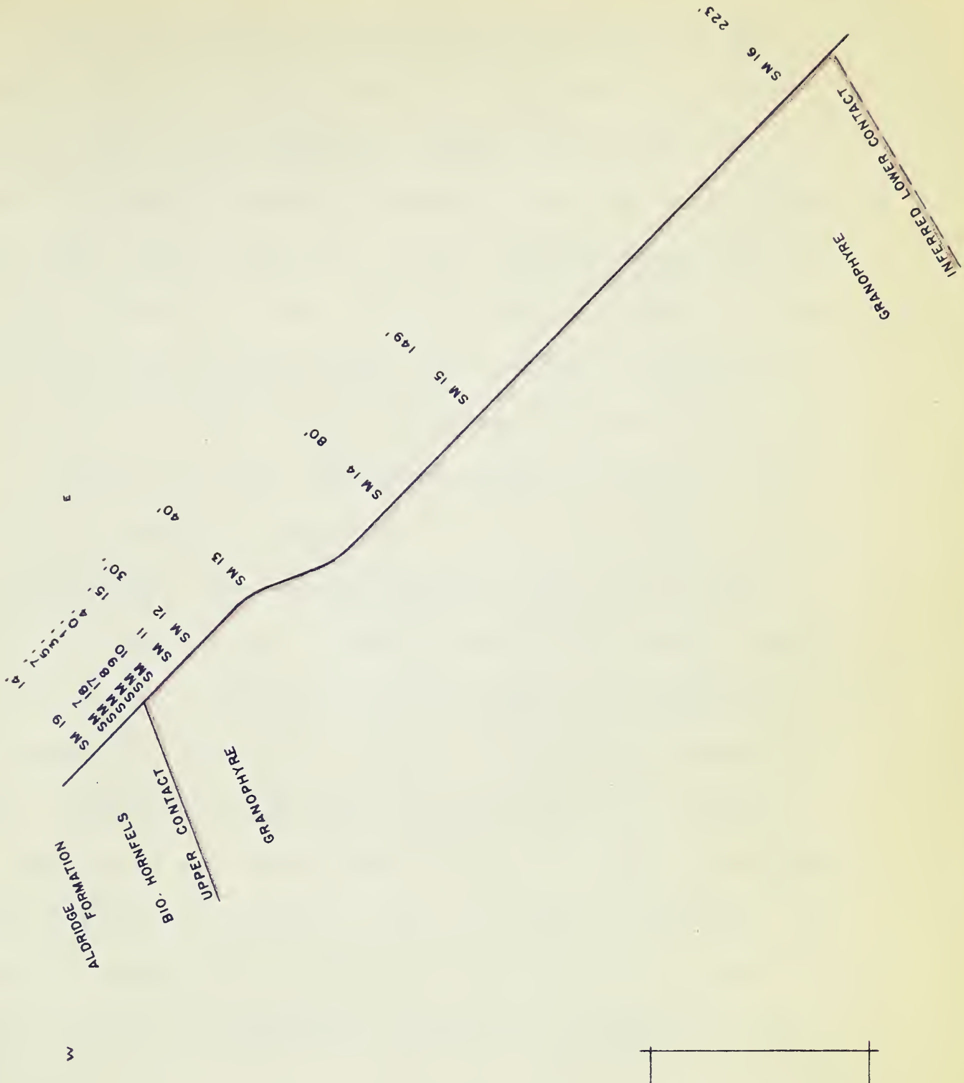
Resort Creek Section - St. Mary "A" sill

Near the headwaters of Resort Creek sill "A", which apparently represents the highest sill stratigraphically in the series, is at least 200 feet thick. A talus slide concealed the base of the sill but a sample of the sill taken 223 feet below the upper contact contained some biotite, indicating that the lower contact with the sediments was being approached.

Samples were collected stratigraphically across the steep east face of this upper "A" sill (see Fig. 2).

The dark green, medium-grained rock is classified as quartz diabase. Its mineral constituents are: amphibole 55-60%, plagioclase 10-25%, quartz 5-20%, secondary minerals 10-30%, and accessories 3-5%. The amphibole is the actinolite variety and the plagioclase is dominantly labradorite. Secondary minerals are calcite, magnetite, epidote, clinozoisite, kaolin, leucoxene, sphene, chlorite, sericite, and hematite. The accessory minerals are biotite, magnetite-ilmenite, apatite, sphene, pyrite, pyrrhotite and rutile.

Fig. 2




LOCATION OF SAMPLES
UPPER SILL
RESORT CREEK SECTION
ST. MARY LAKE B. C.
Scale 1" = 40'

Texture:

The sill is subophitic due to crystallization of the plagioclase before the augite, which was subsequently altered to amphibole. The tabular plagioclase feldspar laths pierce the amphiboles and exhibit a random orientation with some interlocking (see Plate I). Long, interwoven, curved, euhedral amphiboles are poikilitic with small feldspar and quartz grains enclosed as chadacrysts. According to Harker (1932) this texture is developed in rocks in which the amphibole is in great part derived from augite.

Probably the most conspicuous texture exhibited in the sill is the granophyric intergrowth of quartz and feldspar (see Plates III and IV). The term granophyre has been used by some authors in a genetic sense, to refer to acid differentiates formed from basic magmas. It has been used by others as a descriptive term to apply to rocks having intergrowth textures of quartz and feldspar. Granophyric or granophyre is used here in a textural sense, applying to sills characterized by the irregular intergrowth of blebs, patches and threads of quartz in a base of feldspar. It is similar to graphic and micrographic but differs from these textures in that the intergrowth of quartz and feldspars is more irregular.

Different types and amounts of granophyre are distributed throughout the sill. Generally there is a higher concentration of granophyre near the margins of the sill than at the centre with the greatest amount concentrated in the upper portion of the sill. This symplektitic intergrowth is discussed elsewhere in the paper (p. 41 ).

The inferred sequence of crystallization is as follows:

1. Plagioclase, primary magnetite-ilmenite, sphene, apatite
2. Pyroxene, altered to amphibole
3. Epidote, clinozoisite
4. Biotite
5. Chlorite
6. Quartz and alkali feldspar (granophyre)

Mineralogy:

The amphibole of the diabase is actinolite or uralite. In thin section the fibrous amphibole is green, strongly pleochroic and occurs as large, poikilitic, prismatic crystals that are usually twinned. The individual grains range in length from 1 to 5 mm. and average about 3 mm. They are euhedral to subhedral in shape, having formed later than the smaller plagioclase grains which they enclose or partly envelop. In some specimens the amphibole makes up as much as 60 percent of the rock. It is replaced chiefly by chlorite and to a less extent by carbonate, epidote, biotite, magnetite and clinozoisite.

The optical characteristics are: Pleochroism - X = pale yellow, Y = deep green, Z = dark green, $Z > Y > X$; $2V = 80^{\circ}$, optically (-), C to $Z = 17^{\circ}$.

The feldspar of the diabase is mainly sodic labradorite and sodic andesine, although the complete range is from $An_{29}$ to $An_{54}$. The tabular plagioclase laths are highly altered and average 1 mm. in length. In places albite, Carlsbad and pericline twinning are distinct, but as a rule the plagioclase is altered to kaolin, sericite,

clinozoisite, epidote and carbonate.

In some specimens there are two distinctly different kinds of plagioclase. Zoned crystals, having a labradorite core surrounded by a sodic andesine rim are more common near the margins of the sill. Albitization and saussuritization are more complete in the centre of the sill. The plagioclase is replaced by the secondary alteration products, largely epidote and quartz, due to late deuteric action of the magma.

Quartz is erratic in distribution but is always present. It forms up to 20 percent of the rock near the centre of the sill. The grain size is variable but is commonly fine-grained.

Near the boundary of a sill, in contact with the quartzitic sediments, granophyric intergrowths of quartz and feldspar occur in cuneiform and radial textures.

Biotite is abundant near the contacts but is rare in the body of the sill. Yellow-brown, iron-rich flakes range up to 0.5 mm. in length. Some flakes have a pronounced sieve texture and partially replace the amphibole.

Secondary minerals are alteration products of the feldspars and the mafics and make up 10-30 percent of the rock. Common minerals found are epidote, clinozoisite, calcite, chlorite, sericite, kaolin and leucoxene.

There are greater amounts of secondary minerals near the centre of the sill, where late deuteric action was prolonged due to slower cooling, than at the chilled margins. Subhedral grains of epidote and calcite form patches completely replacing the mafics as

well as the feldspars. Veinlets of quartz and epidote are common.

Accessories form up to 5 percent of the rock with sphene as the most abundant mineral. Other common accessories are magnetite, ilmenite, apatite, pyrrhotite, hematite, and pyrite. There are patches of sphene up to 2 mm. in size forming before the amphiboles and probably along with the other accessories such as apatite. Titaniferous magnetite, in part altered to leucoxene, is present in all specimens and may occur as skeletal crystals. Apatite is quite common as long idiomorphic needles. Pyrite, hematite and pyrrhotite occur as small specks. In some cases hematite veinlets were evidently due to outcrop weathering.

## Resort Creek Section Contact Phase - Biotite Hornfels

Field examination of the upper margin of "A" sill on Resort Creek showed a knife edge contact between the diabase and the Aldridge quartzite. The dark green, columnar jointed sill is in sharp contrast with the light grey, rusty weathering quartzite. The intrusive apparently pushed the quartzite apart without impregnating any of these beds.

The sediments were "baked" at least 15 feet above the upper contact with the sill and developed a hornfelsic rock.

Mineralogy:

The rusty weathered, light grey, fine-grained, wall rock consists essentially of interlocking quartz grains with minor amounts of feldspar. The texture is granoblastic. Recrystallized, untwinned

plagioclase may be present but could not be distinguished from quartz. The quartzite would probably show no effect from the intruding action of the sill except the recrystallization to a granoblastic texture.

The argillaceous quartzite bands near the sill contact developed chlorite and biotite ranging up to 30 percent of the rock, through contact metamorphic action.

The main constituents of the fine-grained hornfels are quartz, biotite, chlorite and muscovite. Minor amounts of feldspar, secondary epidote, clinozoisite and accessories such as magnetite, apatite, zircon and rutile are present.

Some quartz grains show undulose extinction, probably due to metamorphic stresses. Sutured intergrowths are common throughout but may be a result of regional metamorphism. The equidimensional grains are tightly interlocked as a mosaic.

Fresh, medium-brown, iron-rich biotite flakes up to 0.3 mm. long are arranged in a decussate structure. This indicates a lack of shearing stress in the rock. Some felted clusters range up to 0.5 mm. in size. There is no development of parallel mica flakes or schistose structure.

Light green, aggregate-polarized chlorite with anomalous blue interference colors is found as isolated grains or associated with biotite or muscovite. In part, the chlorite appears to have replaced the biotite. More commonly the biotite is later than muscovite and chlorite.

No twinned plagioclase grains are observed. Microcline grains with indistinct twinning are present but could not be separated from quartz in routine counting procedures. The potash feldspar content of the rock is estimated at less than 10 percent.

The secondary minerals epidote and clinozoisite are common alteration products. Scattered granular subhedral epidote grains range up to 0.4 mm. in size.

Apatite, zircon, magnetite and rutile are common accessories throughout the rock.

Conclusions:

In summary, the study of the contact phase established that:

(1) A fine-grained, equigranular mosaic texture extended at least 15 feet above the upper contact of "A" sill with the sediments.

(2) There is no appreciable change in grain size throughout the hornfels.

(3) No marked contact exists between the hornfels and the Aldridge formation.

(4) The greatest degree of contact metamorphism produced in the quartzite by the sill is of the biotite facies.

These conclusions do not agree with the interpretations of Daly (1912) and Schofield (1914) but are supported by the concepts of Grout (1932), Rice (1937, 1941) and Swanson and Gunning (1945).

Daly (1912) named the acid rock a biotite granite. The

composition of the granite is very similar to the quartzite above it, both chemically and mineralogically and Daly gave the origin of the granite as a process of assimilation. Schofield (1914) called this acid type (hornfels) a micropegmatite. He disregarded Daly's theory of assimilation for formation of micropegmatite. Essentially his theory was related to depth, where the parent reservoir after undergoing differentiation produced different magmas when tapped at various levels.

According to Grout (1932) a diabase sill, in order to have an acid magmatic differentiate, has to be at least 500 feet thick.

Rice (1937, 1941) stated that the granitic rocks are granitized sediments. His main argument was that he did not find a sharp contact between the granitic (hornfelsic) rocks and sediments.

Swanson and Gunning (1945) agree with Rice's interpretation for rocks developed west of the Sullivan mine, British Columbia.

## The St. Mary "B" Sill

A microscopic examination of one thin section gave the following composition: amphibole 55%, plagioclase 28%, quartz 2%, secondary minerals 14%, accessories 1%.

The amphibole crystals are the green actinolite variety. They are fibrous and pierced by the feldspars, showing relict sub-ophitic texture. A few grains are small, idiomorphic prisms, but most are elongated and poikilitic with enclosed chadacrysts of

feldspars and quartz.

The optical properties are: pleochroism - X = light green, Y = dark green, Z = dark green, $Z > Y > X$ ; $2V = 85^{\circ}$, optically (-), C to $Z = 18^{\circ}$.

The feldspar consists of two types of plagioclase, labradorite ($An_{52}$) and sodic andesine ($An_{30}$). The glassy feldspar laths have albite, pericline and carlsbad twins. Some grains are zoned, but most are of uniform composition.

Minor amounts of quartz occur in the specimen. The secondary minerals include epidote, clinozoisite, kaolinite, sericite, calcite and chlorite. Patches of chlorite and subhedral grains of epidote replace the amphiboles. Common accessories are sphene, titaniferous magnetite, pyrrhotite and apatite.

## The Kimberley Creek Sill

Jure (1929) studied this intrusive between the Sullivan and Kimberley Creek areas, on the eastern limb of the Kimberley anticline. He proposed a differentiation hypothesis for this thick sill.

A study of one thin section from this thick sill gave the following composition: amphibole (actinolite) 32%, plagioclase 26%, quartz 8%, secondary minerals 33%, and accessories 1%.

The green actinolite appears to be largely altered to chlorite and other secondary minerals. The poikilitic, twinned and untwinned amphibole shows a subophitic texture with the feldspar laths. The actinolite contains small feldspar and quartz grains in

a poikilitic texture. The optical properties are: pleochroism - X = light green, Y = dark green, Z = dark green, $Z > Y > X$ ; $2V = 85^{o}$, optically (-), C to Z = $18^{o}$.

The plagioclase feldspar contains different types ranging from calcic labradorite to sodic andesine. Many of the tabular plagioclase laths are clear, glassy and have sharp albite twins and range from $An_{55}$ to $An_{35}$ in composition.

Quartz forms granophyric intergrowths with the feldspar.

Secondary minerals make up a large percentage of the specimens. They include epidote, clinozoisite, kaolin, sericite, calcite, biotite, and chlorite.

Common accessories are patches of titaniferous magnetite altered to leucoxene, sphene, pyrrhotite, pyrite and apatite.

## KINGSGATE AREA, BRITISH COLUMBIA

Daly (1912) made the first real study of the Purcell sills at Kingsgate and referred to them as the Moyie sills.

This section was described in detail by Schofield (1915). The four sills, "A", "B", "C", "D", which are striking north and dipping 60 degrees to the east are exposed on the ridge west of Kingsgate, British Columbia, on the International Boundary line.

Sill "A", the highest in the series, is actually two thin sills with a band of hornfelsic quartzite between. Samples were collected stratigraphically across the upper thin sill and the underlying quartzite. This upper thin sill is at least 30 feet thick.

## Moyie Section - The "A" Sill

The dark green, upper part of the "A" sill intrudes the Aldridge quartzite, developing a well defined hornfelsic rock at the contact. This "granitized" sediment grades into the quartzite. In places the contact metamorphism was sufficient to produce a hornblende, biotite rock. The blue-green, pleochroic hornblende is dissimilar to the amphibole in the adjacent sill.

Mineralogy:

The mineral constituents of sill "A" in the Moyie section are: amphibole 53%, plagioclase 10%, quartz 5%, accessories 2%, secondary minerals 30%.

The amphibole of the sill is usually in plume-shaped crystals or euhedral laths 1 to 3 mm. long. The green actinolite is pleochroic, twinned and fibrous. Optically: X = pale green, Y = green, Z = dark green, $Z > Y > X$ ; 2V varies, but averages near $80^{\circ}$, optically negative, with C to Z = $18^{\circ}$.

The amphibole formed later than the plagioclase and encloses or envelops the feldspar and quartz grains in a poikilitic texture.

In part, chlorite has replaced the amphibole.

The feldspar consists of both labradorite and sodic andesine. The plagioclase occurs in lath-shaped crystals, which show carlsbad, pericline and albite twinning but on the whole are highly saussuritized. Zoning is evident and it shows an inner calcic

core ($An_{54}$) grading to an outer sodic rim ($An_{30}$). Saussuritization is more complete near the centre of the sill, where large amounts of feldspar are altered to secondary minerals.

The quartz in the diabase is predominantly present in association with sodic andesine as granophyric intergrowths. Granophyre is more common near the centre and lower contact of the sill with quartzite. The enrichment in quartz near the margins of the sill may be due to assimilation of quartz from the intruded sediments. The granophyre in the centre of the sill may be largely due to late deuteric or hydrothermal alteration of the cooling sill. Late magmatic alteration is suggested by the presence of large amounts of the secondary minerals from the earlier-formed plagioclase.

Biotite is present in the margin of the sill but is absent in the normal rock. The brown flakes make up 1 percent of the specimen.

Secondary minerals are quite conspicuous throughout and form up to 30 percent near the centre of the sill. The alteration products are kaolin, sericite, epidote, clinozoisite, chlorite and calcite.

Accessories are common. Sphene occurs as wedge-shaped crystals and patches forming up to 2 percent of the rock.

Contact Phase - Upper Moyie "A" Sill:

The rusty-weathering, light grey, fine-grained contact rock has the hard, compact appearance of a recrystallized sediment.

The mineral constituents are interlocking quartz grains and minor amounts of feldspar that are largely altered to secondary

minerals.

The equigranular quartz grains are interlocked in a granoblastic texture. Some of the quartzitic grains range up to 0.5 mm. in size and show undulatory extinction. In parts they exhibit a graphic texture that has been referred to as micropegmatite (Schofield, 1914).

Altered, albite-twinned plagioclase grains and indistinct grid-iron twinned microcline were observed, but only in minor amounts.

Brown biotite is developed near the contact and may make up 30 percent of the rock. It develops from irregular individual flakes, having an average length of 0.15 mm., to more localized blebs as the contact is approached. The biotite is altered to chlorite with the development of fine-grained titanite (Scott, 1954). Strongly pleochroic hornblende, in part euhedral, also replaces the biotite.

The hornblende occurs as euhedral prismatic crystals that range in size up to 1 mm. in length. They are not poikilitic, twinned or fibrous and have a characteristic pleochroism: X = light yellow green, Y = olive green, Z = blue green; $Z > Y > X$. The pleochroism and habit of these amphiboles differs from that in the adjacent sill.

Accessory sphene, apatite, ilmenite, and magnetite are common. Sphene, which has rounded outlines, is probably of detrital sedimentary origin.

## CONTACT RELATIONS OF THE PURCELL SILLS

Many of the sills in the Cranbrook area carry border phases 5-20 feet wide, usually marked by a biotite hornfels. Some contain up to 75 percent amphibole and 20 percent quartz but the rock five feet below the lower contact of "A" sill at Kingsgate has 30 percent biotite and 3 percent amphibole. Plagioclase is present but is much less abundant than in the body of the sill. Quartz forms up to 40 percent of the rock.

Rice (1941) suggested that the amphibole is due to a process of streaming volatiles away from the interior of the sill. The amphibole of the contact phase exhibits different optical properties than the amphibole in the sill, suggesting a difference in chemical composition. Rice concluded that the contact rocks were formed from sediments by a process of granitization, with the development of biotite, hornblende and feldspar in appreciable quantities. Although he had not visited the Moyie sills, his conclusions are in agreement with Swanson and Gunning (1945) and the writer for the interpretations of the contact phase.

# CHAPTER V

## PETROGRAPHY OF TWO SILLS IN THE WATERTON LAKE AREA

Petrographic descriptions were made on two quartz diabase sills in the Waterton Park area: the Blakiston Brook section, and the Lake Alderson section. The study of the Waterton sills was undertaken in the hope of establishing a similarity or difference between the Waterton sills and the sills in the St. Mary Lake and adjacent areas.

## BLAKISTON BROOK SECTION

Diabase sills, mapped by Douglas (1953), intrude the Grinnell formation near Blakiston Brook. The location of the samples is given in Chapter IV. The sill sampled at Blakiston Brook is 50 feet thick, and quite uniform in thickness along strike.

### Petrography

The average mineralogic composition of the Blakiston Brook diabase is pyroxene 17%, plagioclase 18%, quartz 5%, secondary minerals 45%, varietals and accessories 15%.

The pyroxene of the diabase is titaniferous augite that fills the interstices between the feldspar crystals. Corroded reddish brown augite is slightly pleochroic or non-pleochroic. The grains range up to 3 mm. in length in the coarse phase of the sill. Some grains are twinned and some show schiller structure. The optical properties of the augite are: $2V = 62^{o}$, optically (+), C to Z = $45^{o}$.

The larger plagioclase laths are highly altered and a composition determination was very difficult. However, the smaller, later forming grains have $An_{32}$ content. The most sodic plagioclase feldspar is calcic oligoclase $An_{28}$.

Quartz was more abundant near the centre of the sill where it forms granophyric intergrowths with the feldspar. Quartz was never more than 5% of the rock. The low quartz content may be due to the fact that the sill has not assimilated silica from the wall rock.

The secondary minerals form up to 45 percent of the rock, including large amounts of chlorite and magnetite which are probably due to deuteric alteration of sugite.

Reaction rims of skeletal magnetite enclosing chlorite mark the former presence of the mafic minerals, usually augite. Near the centre, or coarser phase of the sill, calcite veins are associated with secondary quartz and the smaller plagioclase feldspar grains. Some of the quartz surrounds the chlorite.

There is considerable alteration of the feldspars to sericite, epidote and kaolinite. Some feldspars are completely saussuritized. The rock is badly fractured and some secondary minerals may be due to outcrop weathering.

The main accessory is titaniferous magnetite, which is surrounded by leucoxene. Large skeletal and spear-shaped grains are primary as distinguished from the later forming magnetite associated with chlorite.

Long, colorless, idiomorphic apatite needles reach a

length up to 3 mm. These acicular grains are probably the chlor-apatite variety.

Near the base of the sill there is an abnormal amount of sphene present, some wedge-shaped in outline, but more commonly in patches of blebs associated with leucoxene.

## LAKE ALDERSON SECTION

Petrographic descriptions were made of five samples of a quartz diabase sill intruding the Siyeh formation of the Lewis Series at Lake Alderson in Waterton Park, Alberta. The location of the samples is given in the Appendix. The Lake Alderson sill is 2200 feet stratigraphically below the basalt flows.

### Petrography

The minerals of the diabase are as follows: pyroxene 21-33%, amphibole 4-8%, plagioclase 9-13%, secondary minerals 36-40%, varietals and accessories 10-15%.

The pyroxene is reddish brown, titaniferous augite and occurs in a diabasic to subophitic texture. The augite is euhedral, twinned and shows varying degrees of corrosion in different parts of the sill. Some of the augite is altered to secondary amphibole, some to chlorite and iron oxide. The augite shows schiller structure. The optical properties of augite are: $2V = 62^{o}$, optically (+), C to Z = $45^{o}$.

The amphibole consists of primary brown hornblende and secondary green amphibole or uralite. Both the augite and brown

hornblende can be seen microscopically changing to the green uralite. The optical properties of the two hornblendes are:

brown hornblende:- pleochroism - X = light brown, Y = red brown, Z = red brown, $Z > Y > X$ ; $2V = 72^{o}$, optically (-), C to Z = $15^{o}$.

green amphibole:- pleochroism - X = light green, Y = dark green, Z = dark green, $Z > Y > X$ ; $2V = 80^{o}$, optically (-), C to Z = $17^{o}$.

The feldspar of the diabase is labradorite and sodic andesine. The small tabular, glassy twinned plagioclase at the contact have $An_{54}$ composition and are oriented parallel to the margins of the sill. Many grains are saussuritized and zoning shows a calcic feldspar core ($An_{54}$) to a sodic andesine rim ($An_{34}$). Small, glassy grains of late-forming plagioclase are generally sodic andesine in composition. Some of the plagioclase occurs as a granophyric intergrowth with quartz near the centre of the sill.

Quartz is always present but forms less than 10 percent of the rock. Near the centre of the sill it occurs in the greatest amount, partly in a granophyric texture.

The secondary minerals such as calcite, epidote, clinozoisite, kaolinite, sericite, chlorite and magnetite form up to 48 percent of the rock.

Large amounts of calcite occur in the coarse phase of the sill where the feldspars are highly altered.

Reaction rims are common in the diabase. Near the basal contact of the sill kelphitic rims of chlorite, ilmenite and limonite are very well developed. Iron-rich chlorite replaces the mafics with a rim of magnetite outlining the former mineral grains (see Plate II, fig. 2).

Titaniferous magnetite is present in all the specimens and may form up to 15 percent of the rock. Most of the titaniferous magnetite is surrounded by leucoxene. The large, octahedral and skeletal crystals of iron oxide are counted as primary in origin. The magnetite grains associated with the chlorite and forming reaction rims are considered to be the result of late deuteric action upon the early-formed mafic minerals.

Accessory sphene and chlor-apatite are conspicuous in every thin section and form up to 2 percent of the rock. Pyrite, pyrrhotite and hematite occur as small blebs.

## PETROGRAPHY OF THE CONTACT ROCKS OF THE BLAKISTON BROOK & LAKE ALDERSON SILLS

The contacts of the sills with the sediments at Blakiston Brook and Lake Alderson in Waterton Park, Alberta, are a calc-flintas (Harker, 1932). Contact metamorphism produces a change in the carbonate rock over a zone 5 to 10 feet wide. The calc-flinta is green in color, cherty-looking and appears to be vesuvianite, epidote, wollastonite and garnet.

Ramberg believes that the most important processes of contact metasomatism are caused by the difference in composition of the surrounding rocks and of the gases and solutions from the magma masses. A hornfels is produced where the sills intrude a quartzitic country rock but the sill develops a calc-flintas, where a carbonate rock is intruded. In both cases a high temperature gradient existed between the hot diabase magma and the solidified

country rock.

## PETROGRAPHY OF THE LOGAN PASS SILL

The southward extension of the sill found at Lake Alderson passes beneath the parking lot at Logan Pass, Glacier National Park, Montana. Dyson (1949) remarked on the uniformity of the sill, about 100 feet thick, extending along strike for some 20 miles.

The mode, based on one thin section, is: pyroxene 8%, amphibole 20%, plagioclase 15%, quartz 10%, secondary minerals 36%, varietals and accessories 11%.

The pyroxene of the sill is red brown, titaniferous augite interwoven with tabular plagioclase laths in a subophitic texture. Cores of augite are surrounded by uralitized, green amphibole. Some of the augite is replaced by chlorite and magnetite.

Amphibole makes up 20 percent of the specimen occurring as primary brown hornblende and secondary green amphibole. The optical characteristics are:

brown hornblende:- pleochroism - X = light brown, Y = dark brown, Z = dark brown, $Z > Y > X$ ; $2V = 70^{\circ}$, optically (-), C to Z = $15^{\circ}$.

green amphibole:- pleochroism - X = light green, Y = dark green, Z = dark green, $Z > Y > X$ ; $2V = 80^{\circ}$, optically (-), C to Z = $17^{\circ}$.

The feldspars of the sample are saussuritized plagioclase laths. Some of the smaller glassy grains are of andesine composition ($An_{35}$). The larger plagioclase feldspars, which were originally more

calcic than andesine, are altered to secondary minerals. No fresh plagioclase more calcic than $An_{35}$ was observed.

Quartz forms up to 10 percent of the specimen. Intergrowths of quartz and feldspar exhibit granophyric texture. Some quartz grains are 1 mm. in size.

Subhedral grains of intersertal epidote up to 2 mm. in length replace the feldspar as well as the mafic minerals. Iron-rich chlorite replaces the mafics, surrounded by magnetite forming a reaction rim and outlining the former mineral.

Skeletal and octahedral crystals of titaniferous magnetite, which is largely altered to leucoxene, are quite evident. Primary acicular apatite needles and sphene make up 2 percent of the rock.

# CHAPTER VI

## MODE OF EMPLACEMENT AND ALTERATIONS ASSOCIATED WITH THE PURCELL DIABASES

Recent studies of the Purcell Series, particularly those of Reesor (1957), suggest that a pre-Purcell cratonic area was located to the east of the present site of the Purcell Mountains. Sediments derived from this craton accumulated in the Beltian geosyncline, with a general thickening from east to west of the series as a whole. If these spatial relations are accepted, certain concepts may be evolved. If the concepts match the observed data, they may be a valid explanation of the regional geologic history. In the following paragraphs several unproved concepts are set forth for evaluation.

### MODE OF EMPLACEMENT

A hinge belt lay between the Beltian geosyncline to the west and the cratonic shelf to the east. The hinge line extended from the present site of the Rocky Mountains in eastern British Columbia south to the Snake River Plain in Idaho. It was a zone of weakness in the crust which was responsive to stresses in the geosyncline. Tension fractures and fissures within the geosyncline allowed huge tabular basaltic intrusives to come up into the sedimentary strata.

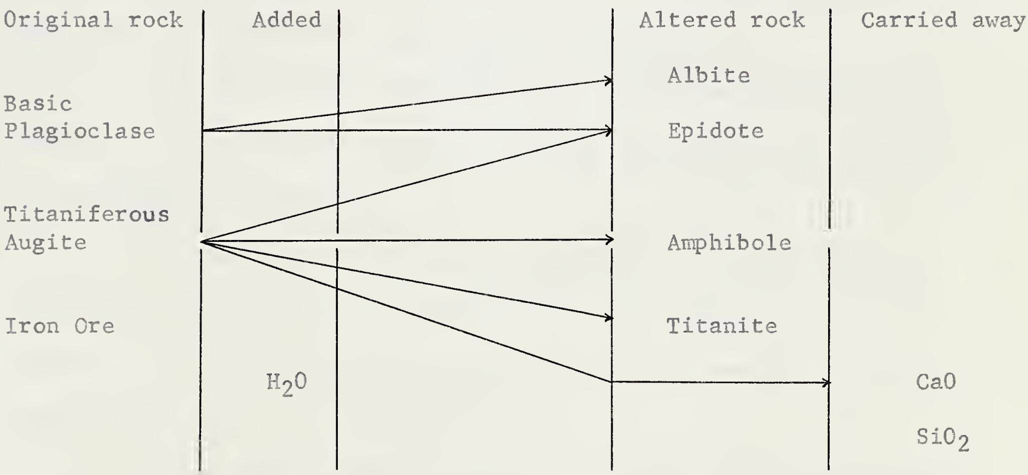
The phenomenon of chilling displayed by fine-grained border facies of the sills testifies to their igneous origin. Low grade contact metamorphism caused alterations of the sills and surrounding rocks. The diabasic sills were attacked by their own late magmatic

fluids and fell victim to autometamorphism. The present mineral associations of the Purcell sills reflect the different cooling histories of the different sills, which in turn are related to the depth of intrusion and the thickness of the sill.

## ALTERATIONS ASSOCIATED WITH THE PURCELL SILLS

The mineralogical alterations of the Purcell diabase following intrusion may be compared to those in a basalt found in the outer contact zone of the Oslo region, Norway (Barth, 1952, p.322).

Scheme of Reactions Taking Place in Basaltic Rock




Three types of alteration will be discussed in the following paragraphs: amphibolization, saussuritization, and granophyric alteration.

## Amphibolization

The development of a secondary amphibole or uralite from pyroxene is a relatively common deuteric alteration in a basic intrusive and is called amphibolization. Many of the previous workers on the Purcell sills consider the amphibole to be a uralite, or secondary hornblende; most identify it as actinolite. The optic properties of the amphiboles have been discussed extensively in previous papers, both in Canada and south of the International Boundary.

F.C. Calkins (1909), after studying the northwestern Montana sills, surmised that the amphibole is secondary and suggested that these rocks are uralitized diabase and gabbro.

R.A. Daly (1912) concludes that the fibrous amphibole is secondary after the compact form. He found no trace of any pyroxene or pseudomorphs of pyroxene.

S.J. Schofield (1915) found pyroxene in varying stages of alteration to uralite in the Purcell sills. He states that pyroxene changed to a fibrous amphibole which in turn was changed to a more compact amphibole.

A.L. Anderson (1930) found that amphibole in several of the Precambrian sills of the Clark Fork district, Idaho, contained cores of hypersthene and augite. He suggests that the amphibole in all these sills had replaced pyroxene. Kirkham and Ellis (1926) were of the same opinion concerning the amphibole in the Precambrian sills in Boundary County, Idaho.

Gibson and Jenks (1938) have discussed more fully the amphibolization of the sills in northwestern Montana. They believe the amphibolization to have been caused by hydrothermal solutions related to Mesozoic granitic intrusives.

Rice (1941) concludes that the amphibole is probably an alteration product of pyroxene. In one instance pyroxene occurs partly replaced by amphibole.

Conclusions:

No pyroxene was recognized by the author in the St. Mary Lake, Kingsgate and Kimberley sills. The writer believes that a prolonged cooling history for these sills permitted complete transformation of pyroxene into amphibole.

In the Waterton Lake area the amphibolization of the sills was arrested by more rapid cooling and both pyroxene and amphibole are present.

The difference in rate of cooling may be related to depth of intrusion. The sills in the St. Mary Lake and Kingsgate area are 26,000 feet stratigraphically below the Purcell lavas while the Waterton sills are only 2200 feet below the flows. The precise location within the sill of the pyroxene described by Schofield (1914) and Rice (1941) is not given. If hypersthene is present it would normally occur within the lower third of the thick sills (Turner and Verhoogen, 1951). The basal parts of the thick sills were not sampled in this study.

## Saussuritization

Saussuritization is widespread in the sills. Near the fine-grained borders of the sills the most calcic plagioclase feldspar found was labradorite. Grains of plagioclase, zoned from a labradorite core to a sodic andesine rim, are prominent throughout the sills. The original basic plagioclase is attacked and altered to an aggregate of a less calcic plagioclase, sericite, epidote, clinozoisite, calcite and secondary quartz. The production of the saussurite group of minerals is not restricted to the alteration of the feldspar alone, as can be seen in the diagram from Barth.

Saussuritization is produced by hot residual magmatic solutions acting on mafic and felsic minerals. The fact that this alteration is so widespread, and reported in a similar pattern from all the sills examined, supports the theory of a late deuteric origin for the saussuritized sills.

## Granophyric Alteration

Granophyric intergrowths are conspicuous in the marginal portions of various diabase sills intruding the Purcell and Lewis rocks. Granophyres may be either a product of reaction between the diabase magma and invaded quartzites, or the acid residium from the magma formed by differentiation. Gravitational differentiation seems to be ineffective in sills less than 500 feet thick (Grout, 1932).

Granophyric rocks have a texture characterized by the irregular intergrowth of blebs, patches and threads of quartz in a

base of feldspar. In the Purcell sills the feldspar is sodic andesine. Some degree of textural intergrowth involving quartz and feldspar is present in every rock. The degree and pattern of the intergrowth is quite variable.

Leighton (1954), in a study of Proterozoic sills in northern Wisconsin, describes several types of texture which are comparable to those in the Purcells. These are: cuneiform, myrmekitic, irregular, radial and spherulitic.

Cuneiform type (Pl. III, figs. 1, 2) - Most authors describe this type as an ordinary micropegmatitic texture. It shows a regular pattern of wedge-shaped intergrowths of quartz and alkali feldspar.

Myrmekitic type (Pl. III, fig. 3) - A gradation may exist between this and the above types. The myrmekitic type shows elongated blebs or wormlike patches of quartz in feldspar.

Irregular type (Pl. IV, figs. 2, 3) - This type has a less regular degree of intergrowth.

Radiating or Radial type (Pl. IV, fig. 1) - This type possesses a radial arrangement of intergrowths usually cuneiform or myrmekitic in character. It may consist of a central core of feldspar from which the intergrowths radiate outwards.

Spherulitic type - This spherulitic intergrowth is feathery in shape and on a finer scale than the radiating type. However, this type was not recognized in the thin sections that were examined.

Each type of intergrowth may appear by itself in one thin section. The gradational relationships in the degree of development

of granophyric texture is not known. A decreasing anorthite content in the plagioclase feldspar tends to promote the development of intergrowths. The sodic andesine type plagioclase was found to be the most likely host for the quartz blebs.

Origin of Granophyric Texture:

Several possible theories may explain the formation of granophyre. These are:

(1) Primary - (a) eutectic crystallization

(b) simultaneous crystallization without eutectics

(2) Secondary - (a) deuteric action or hydrothermal alteration

(b) solid diffusion or some other granitization process.

The origin of granophyric texture has been discussed exhaustively and may be still unsolved. Some writers suggest that the intergrowths may have both primary and secondary origins.

Vogt supports the concept of eutectic crystallization but the finding of a wide variation in amounts of quartz to feldspar in the intergrowth eliminates the possibility of a eutectic relation.

Wahlstrom states that crystal forces can produce the same features regardless of replacement origin or simultaneous growth. Simultaneous crystallization and replacement probably occur together.

The occurrence of granophyre in unaltered diabases supports primary origin. In the present example the evidence favors quartz replacement of feldspar to give the granophyric intergrowth.

# CHAPTER VII

# GEOCHRONOLOGY

Age dating was undertaken to establish an age for the intrusion of the Purcell sills. The presence of biotite in the hornfels at the contact of the sill provides an opportunity to obtain an age by the potassium-argon method.

## COLLECTION OF SAMPLES

Two hornfels samples were collected from the upper "A" sill contact at Kingsgate, British Columbia.

Sample No. M-5B - 5 feet below the lower contact of "A" sill

Sample No. M-6 - 35 feet below the lower contact of "A" sill.

One hornfels sample was collected from the upper or "A" sill contact at St. Mary Lake, British Columbia.

Sample No. SM-8 - 2 feet above the upper contact of "A" sill.

## PREPARATION OF MATERIAL

The hornfelsic rock containing the biotite was mechanically crushed and pulverized. The disaggregated sample was put through a series of sieves consisting of the following screen sizes, 35, 60, 80, 100, and 200 meshes to the inch (U.S. Sieve Series).

The material on the 200 mesh screen was transferred to a clean piece of paper and spread out in very thin films. A small hand magnet was then used to extract the highly magnetic fraction.

The sample on the 200 mesh screen was separated into light

and heavy fractions using the heavy liquid tetrabromoethane (sp. gr. 2.96 at 20$^{\circ}$ C.). The heavy fraction of the sink and float method was further separated into different magnetic fractions using a Frantz isodynamic separator. The strongly magnetic fraction was removed from the sample at a current strength of 0.2 amps. The setting of the Frantz separator was constant at a slope of 15 degrees and a tilt of 8 degrees. A setting of 0.4 amps. effectively removed all the biotite from the sample. The above procedure was repeated several times to obtain a purer sample.

The biotite sample still contained some other minerals but the biotite was removed by hand picking. The sample was passed over a series of paper sheets, allowing the biotite flakes to adhere to the paper. This separation was rather tedious but effectively produced a purer biotite sample.

The three samples of biotite were dated by H. Baadsgaard. Argon extraction for sample M-6 was made at the University of Minnesota. Samples M-5B and SM-8 were put through the recently completed argon line at the University of Alberta. All mass spectrometric measurements were done at the University of Minnesota.

## RESULTS

The potassium-argon age determinations received from H. Baadsgaard are as follows:

| Sample No. | Location | Potassium analysis | $A^{40}/K^{40}$ | Age |
|---|---|---|---|---|
| M-5B | Kingsgate, B.C. | 2.77% K | $0.0408_7$ | 620 m.y. |
| M-6 | Kingsgate, B.C. | 2.49% K | $0.0392_1$ | 600 m.y. |
| SM-8 | St. Mary Lake, B.C. | 5.49% K | $0.0200_5$ | 329 m.y. |

All dates for the above samples were calculated using:

$$\lambda_e = 0.557 \times 10^{-10} \text{ yrs.}$$

$$\lambda_\beta = 0.472 \times 10^{-9} \text{ yrs.}$$

$$R = 0.118$$

INTERPRETATIONS AND COMPARISON

Age determinations by isotopic composition of galena samples have been made by Cumming, Wilson, Farquhar and Russell (1955) on galena ore specimens from the Sullivan Mine and North Star Hill Mine, Kimberley, B.C. They determined the ore to be 1170 $\pm$ 200; 990 $\pm$ 200 and 995 $\pm$ 200; 1020 $\pm$ 200 m.y. respectively.

Uranium-lead age determinations have been obtained by Kerr and Kulp (1957) on three different pitchblende specimens from the Sunshine Mine, Coeur d'Alene district, Kellogg, Idaho. The uranium samples were taken from veins occurring in the fractured St. Regis formation of the Beltian sediments. The isotopic ages ($Pb^{207}/Pb^{206}$) for the three samples of pitchblende are 885 $\pm$ 50 m.y.; 1190 $\pm$ 30 m.y. and 1035 $\pm$ 35 m.y.

Kerr and Kulp (1952) gave an age of 850 $\pm$ 50 m.y. for uraninite from the Sunshine Mine in an earlier paper.

A possibility exists whereby the lead and uranium ore deposits, located in the Purcell rocks, could have been mobilized from a pre-Purcell basement by Paleozoic or Mesozoic tectonic activity. The dates calculated from the lead isotope ratios give the time of separation of the lead from the earth's mantle. The apparent age of a galena sample in its present deposit may be older than its final time of crystallization.

The two values of 600 and 620 million years determined for the biotite from the contact of the Purcell intrusion at Kingsgate, British Columbia, have a 3% difference but are within estimated analytical error. The lower figure of 329 million years determined for the biotite sample from the St. Mary sill may reflect argon leakage caused by the heating effect of Mesozoic intrusives in the St. Mary Lake area.

The age of approximately 600 million years determined at Kingsgate represents the minimum age of the Purcell sills. This age may also be too low due to argon leakage. However, if the Purcell intrusives and extrusives are of the same age the depositional and erosional processes represented by the Upper Purcell and Windermere Series could have been completed between 600 and 470 million years ago. A date of 470 million years probably corresponds quite closely to the time of deposition of the Lower Cambrian Cranbrook formation which unconformably overlies the Proterozoic formations.

# CHAPTER VIII

## SUMMARY AND CONCLUSIONS

The Purcell Series represents a large volume of sediments apparently derived from an eastern source (Reesor, 1957). The 11,000 feet of dolomitic and calcareous sediments now preserved in the section at Waterton Lake are believed to represent the near-shore equivalents of the 45,000 feet of fine clastics forming the Purcell Series to the west. This wedge-shaped assemblage of sediments is compared by Reesor (1957) to the present Mississippi delta deposits of the Gulf Coast geosyncline.

The Purcell intrusions have mineral compositions and textures which can be related to deuteric alteration and autometamorphism of quartz diabase sills. No pyroxene was recognized by the author in the St. Mary Lake, Kingsgate and Kimberley sills. The writer believes that a prolonged cooling history for these sills permitted complete transformation of pyroxene into amphibole as shown by the relict subophitic texture. Schofield (1914) reports pyroxene in the thick St. Mary sill, but the basal parts of the thick sills were not sampled in this study. In the Waterton Lake area the uralitization of the sills was arrested by more rapid cooling, and pyroxene and amphibole are present in a diabasic texture. Augite and brown hornblende can be seen microscopically changing to the green amphibole. The green amphiboles and the most basic plagioclase feldspars of both the St. Mary Lake and Waterton Lake diabases when compared show similar optical properties.

The present mineral associations of the Purcell sills reflect the different cooling histories of the different sills, which in turn are related to the depth of intrusion. The sills in the St. Mary Lake area are 26,000 feet stratigraphically below the Purcell lavas while the Waterton sills are only 2200 feet below the flows. This concept is based on the assumption that the Purcell sills and flows are genetically related and were emplaced contemporaneously. Recent detailed mapping by the Geological Survey of Canada shows similar quartz-diorite intrusions cutting the Upper Purcell strata, but the age of these intrusions remains in doubt. Basic dykes of at least two ages are reported in the Purcell equivalents of Montana and Idaho.

Due to contact metamorphism, a fine-grained, equigranular, biotite hornfels was developed adjacent to the contacts of the Purcell sills with the sediments. The biotite offered a possibility of dating the time of intrusion. The potassium-argon age of approximately 600 million years determined at Kingsgate, British Columbia, represents the minimum age of the Purcell sills. This age may be too low due to the heating effect of the Mesozoic intrusives, which would cause argon leakage. However, if the Purcell intrusives and extrusives are of the same age, the events following the intrusion of the Purcell magma could have taken place in the available time since that date.

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A P P E N D I X

PLATE I

Relict Subophitic Textures
Crossed nicols, x 80

fig. 1. SM-9, St. Mary Sill Contact

Plagioclase feldspar laths
piercing green amphiboles

fig. 2. SM-10, St. Mary Sill, 4 feet below upper contact

Plagioclase feldspars interwoven
with green poikilitic amphiboles

fig. 3. SM-10

Plagioclase feldspars intergrown
with green twinned amphiboles

PLATE I

fig. 1

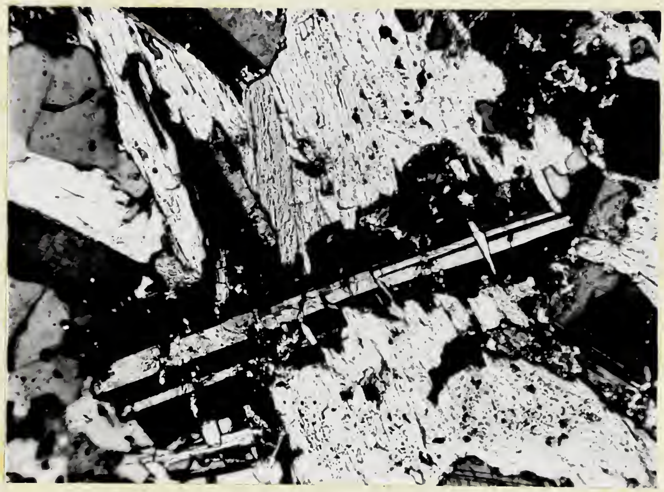

fig. 2

fig. 3

PLATE II

Mafic Minerals
Crossed nicols, x 80

fig. 1. SM-12, St. Mary Sill, 30 feet below upper contact

A curved, twinned, green poikilitic amphibole showing a rosette texture

fig. 2. 3176, Lake Alderson Sill Contact

A reaction rim of limonite, magnetite, chlorite, surrounding an augite core

fig. 3. 3179, Lake Alderson Sill, 5 feet below upper contact

Minerals shown are twinned brown hornblende, prismatic apatite needles, and magnetite

PLATE II

fig. 1

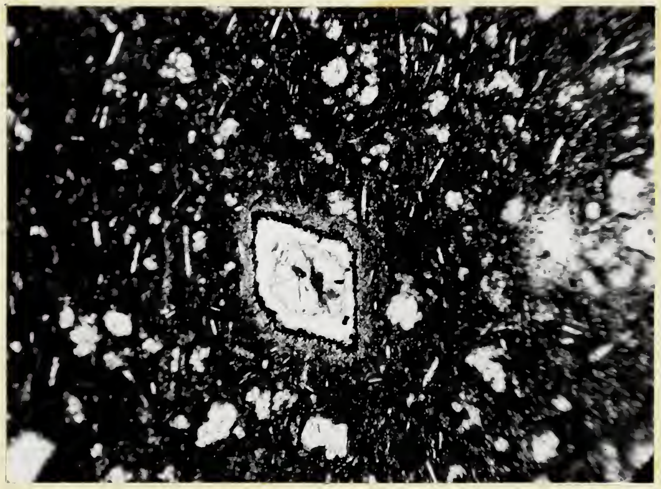

fig. 2

fig. 3

PLATE III

Granophyric Alteration
Crossed nicols, x 80

fig. 1. 2999, Logan Pass Sill

Cuneiform type of intergrowth texture

fig. 2. M-2, Moyie Sill, 10 feet above lower contact

Cuneiform type of intergrowth texture

fig. 3. M-3, Moyie Sill Contact

Myrmekitic type of intergrowth texture

PLATE III

fig. 1

fig. 2

fig. 3

V

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected Sept. 1957
Collector G. Hunt

Specimen No. SM-19 3074
Locality St. Mary Lake, B.
Reference

I. FIELD NOTES
Occurrence: Resort Creek Section
Question: 14 ft. above upper contact "A" sill

II. HAND SPECIMEN DESCRIPTION
Color: f.s. light grey w.s. rusty
Grain size fine grained
Texture: massive
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: quartzitic, granoblastic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Quartz | 60 | Epidote-clinozoisite | | Biotite | 20 |
| Microcline | 10 | | | Muscovite | 10 |
| Varietal (x) | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Magnetite | | | | | |
| Hematite | 1 | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Fresh brown Biotite flakes ranging up to 0.3 mm. in size, some felted clusters.
2. Quartz grains of 0.1 mm. average size in a characteristic mosaic with sutured intergrowths and few strain shadows.
3. Muscovite in 0.2 mm. shreds.
4. Hematite veinlet due to outcrop weathering.

NOTE Microcline grains with indistinct twinning were recognized, but could not be separated from quartz in routine counting procedures. The K-feldspar content of the rock is estimated at 10%. No twinned plagioclase grains were observed.

Biotite hornfels G. Hunt

CLASSIFICATION PETROGRAPHER

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957
Collector G. Hunt, R.A. Burwash

Specimen No. SM-7 2893
Locality St. Mary Lake, B.C.
Reference

I. FIELD NOTES
Occurrence: Resort Creek Section
Question: 7 ft. above upper contact "A" sill

II. HAND SPECIMEN DESCRIPTION
Color: f.s. light grey w.s. rusty
Grain size fine to very fine grained
Texture: massive
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: quartzitic, granoblastic
Structure: original laminated secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Quartz | 60 | | | Chlorite | 15 |
| Microcline | 10 | Epidote | 4 | Biotite | 10 |
| | | Clinozoisite | | | |
| | | Muscovite | | | |
| Varietal (x) | | | | | |
| | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Apatite | 1 | | | | |
| Magnetite | | | | | |

SPECIAL FEATURES:

1. Fresh biotite flakes with average size 0.15 mm., some 0.3 mm.
2. Few quartz grains 0.2 mm. but majority less than 0.1 mm. with sutured intergrowths and some strain shadows.
3. Chlorite with anomalous blue colors replacing biotite.
4. Few granular epidote patches 0.4 mm.
5. Magnetite veinlet.

Biotite hornfels

CLASSIFICATION

G. Hunt

PETROGRAPHER

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected Sept. 1957
Collector G. Hunt

Specimen No. SM-18 3061
Locality St. Mary Lake, B.C.
Reference

I. FIELD NOTES
Occurrence: Resort Creek Section
Question: 5 ft. above upper contact "A" sill

II. HAND SPECIMEN DESCRIPTION
Color: f.s. light grey w.s. rusty
Grain size fine grained
Texture: massive
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: quartzitic, granoblastic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Quartz | 65 | Epidote | 3 | Biotite | 18 |
| Microcline | 10 | Clinozoisite | | | |
| | | Chlorite | 1 | | |
| Varietal (x) | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Magnetite | 1 | | | | |
| Zircon | | | | | |
| rutile | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Fresh tabular biotite flakes up to 0.3 mm., some felty clusters 0.5 mm. size.

2. Quartz grains range from 0.1 mm. to 0.2 mm.

Biotite hornfels
CLASSIFICATION

G. Hunt
PETROGRAPHER

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DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

SM-17

Date Collected Sept. 1957
Collector G. Hunt

Specimen No. 3060
Locality St. Mary Lake, B.C.
Reference

I. FIELD NOTES
Occurrence: Resort Creek Section
Question: 3 ft. above upper contact "A" sill

II. HAND SPECIMEN DESCRIPTION
Color: f.s. light grey w.s. rusty
Grain size fine grained
Texture: massive
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: quartzitic, granoblastic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Quartz | 60 | Epidote | 5 | Biotite | 18 |
| Microcline | 10 | Clinozoisite | | Chlorite | 7 |
| Varietal (x) | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Magnetite | 1 | | | | |

SPECIAL FEATURES:

1. Fresh biotite flakes average 0.2 mm. in size, some 0.5 mm.

2. Few quartz grains up to 0.3 mm. but average less.

Biotite hornfels

CLASSIFICATION

G. Hunt

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DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected: Sept. 1957
Collector: G. Hunt, R.A. Burwash

Specimen No. SM-8 2894
Locality: St. Mary Lake, B.C.
Reference

I. FIELD NOTES
Occurrence: Resort Creek Section
Question: 1 ft. above upper contact "A" sill

II. HAND SPECIMEN DESCRIPTION
Color: f.s. light grey w.s. rusty
Grain size: fine grained
Texture: massive
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: quartzitic, granoblastic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Quartz | 60 | | | Biotite | 18 |
| Microcline | 10 | Chlorite | | | |
| | | Muscovite | 10 | | |
| | | Epidote | | | |
| Varietal (x) | | Clinozoisite | | | |
| | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Apatite | 1 | | | | |
| Zircon | | | | | |
| Magnetite | | | | | |

SPECIAL FEATURES:

1. Fresh biotite flakes up to 0.2 mm., some clusters are 0.5 mm. in size.
2. Quartz grains with quartzitic intergrowths are 0.1 mm. in size.
3. Some chlorite replacing the biotite.

NOTE
No appreciable change in grain size in this contact rock.
Microcline twinning was seen in minor amounts throughout the hornfels.
The recrystallization of the feldspar and quartz into a fine grained equigranular mosaic made it difficult to separate the minerals.
No albite or carlsbad twinned plagioclase grains were recognized.
The greatest degree of contact metamorphism produced by the sill was the biotite zone.

Biotite hornfels
CLASSIFICATION

G. Hunt
PETROGRAPHER

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DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957
Collector G. Hunt, R.A. Burwash

Specimen No. SM-9 2895
Locality St. Mary Lake, B.C.
Reference

I. FIELD NOTES
Occurrence: Resort Creek Section
Question: upper contact "A" sill with the Aldridge quartzites

II. HAND SPECIMEN DESCRIPTION
Color: f.s. medium greyish green w.s. iron stained
Grain size medium grained, 1-3 mm.
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: hypidiomorphic, subophitic, granophyric
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 60 | Epidote-clinozoisite | 5 | Biotite | 6 |
| Plagioclase | 15 | Kaolinite-sericite | 6 | | |
| Quartz | 5 | Calcite | | | |
| Varietal (x) | | Magnesium chlorite | | | |
| Sphene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Pyrite | | | | | |
| Pyrrhotite | | | | | |
| Magnetite | 1 | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Tabular plagioclase feldspar laths up to 1 mm. in length, some curved, bent and altered to secondary minerals, pierce the amphiboles in a subophitic texture. Plagioclase An52, zoned plagioclase range An54 to An36.
2. Twinned, green, pleochroic, poikilitic amphiboles with enclosed small feldspar grains are the Actinolite variety. Some are quite fibrous.
3. Biotite flakes up to 0.5 mm. in length replacing the amphiboles.
4. Intersertal secondary minerals such as
granular epidote with anomalous blue interference color and
magnesium chlorite with very low interference color and aggregate structure.
5. Minor intergrowths of quartz and feldspar.
6. Pyrite and pyrrhotite present.
7. Patches of sphene which formed before the amphiboles.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957

Collector G. Hunt, R.A. Burwash

Specimen No. SM-10 2896

Locality St. Mary Lake, B.C.

Reference

I. FIELD NOTES

Occurrence: Resort Creek Section

Question: 4 ft. below upper contact of "A" sill with the Aldridge quartzite

II. HAND SPECIMEN DESCRIPTION

Color: f.s. Medium greyish green w.s. iron stained

Grain size medium to coarse, 1-3 mm.

Texture: holocrystalline, phaneritic

Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION

Texture: hypidiomorphic, subophitic

Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 55 | Epidote-clinozoisite | 12 | | |
| Plagioclase | 13 | Kaolinite-sericite | 10 | | |
| Quartz | 7 | Magnesium chlorite | | | |
| Varietal (x) | | Calcite | | | |
| Sphene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Magnetite | 1 | | | | |
| Hematite | | | | | |
| Zircon | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Plagioclase feldspar laths up to 1 mm. in length, two types An53 and An35 are partly saussuritized.
2. Twinned, poikilitic, green amphiboles (3 mm.) with enclosed feldspar chadacrysts. Feldspars and amphiboles show relict subophitic textures.
3. Intersertal epidote-clinozoisite.
4. Cuneiform intergrowths of quartz and feldspar (4%).

Quartz diabase

CLASSIFICATION

G. Hunt

PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957
Collector G. Hunt, R.A. Burwash

Specimen No. SM-11 2897
Locality St. Mary Lake, B.C.
Reference

I. FIELD NOTES
Occurrence: Resort Creek Section
Question: 15 ft. below upper contact of "A" sill with the Aldridge quartzites

II. HAND SPECIMEN DESCRIPTION
Color: f.s. medium greyish green w.s. iron stained
Grain size medium 1-3 mm.
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: hypidiomorphic, subophitic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 58 | Epidote-clinozoisite | 5 | | |
| Plagioclase | 10 | Kaolinite-sericite | 20 | | |
| Quartz | 5 | Calcite | | | |
| | | Leucoxene | | | |
| Varietal (x) | | Magnesium chlorite | | | |
| Sphene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Magnetite | 1 | | | | |
| Ilmenite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Plagioclases are cloudy and largely altered to secondary minerals, An51.
2. Green, pleochroic, twinned uralite or secondary amphiboles are poikilitic with earlier crystallized feldspar and quartz as chadacrysts. Some are subhedral. Actinolite - $2V = 80^{o}$; opt. (-); C to Z = $17^{o}$.
3. Granophyre with blebs of quartz intergrown with feldspar (3%).
4. Titaniferous magnetite altered to leucoxene.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957
Collector G. Hunt, R.A. Burwash

Specimen No. SM-12 2898
Locality St. Mary Lake, B.C.
Reference

I. FIELD NOTES
Occurrence: Resort Creek Section
Question: 30 ft. below upper contact of "A" sill with the Aldridge quartzites

II. HAND SPECIMEN DESCRIPTION
Color: f.s. medium greyish green w.s. iron stained
Grain size medium to coarse 1-5 mm
Texture: holocrystalline, phaneritic, hypidiomorphic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: subophitic, granophyric, rosette
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 60 | Epidote-clinozoisite | 15 | | |
| Plagioclase | 13 | Kaolinite sericite | | | |
| Quartz | 7 | Calcite | | | |
| | | Magnesium chlorite | | | |
| Varietal (x) | | | | | |
| Sphene | 3 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Titaniferous magnetite | 2 | | | | |
| Zircon | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Plagioclase feldspars An54 and An30 showing saussuritization to intersertal secondary minerals.
2. Twinned, poikilitic, green secondary amphiboles (up to 5 mm long) in rosette structures.
3. Well developed cuneiform and radial granophyre (5%).
4. Subhedral epidote-clinozoisite.
5. Intergranular iron ores.
6. Coarse phase of sill.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

SM-13

Date Collected April 1957 | Specimen No. 2899

Collector G. Hunt, R.A. Burwash | Locality St. Mary Lake, B.C.

Reference

I. FIELD NOTES

Occurrence: Resort Creek Section

Question: 40 ft. below upper contact of "A" sill with the Aldridge quartzites

II. HAND SPECIMEN DESCRIPTION

Color: f.s. medium greyish green w.s. iron stained

Grain size medium to coarse, 1-5 mm.

Texture: holocrystalline, phaneritic

Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION

Texture: hypidiomorphic, granophyric

Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 55 | Epidote-clinozoisite | 20 | | |
| | | Kaolinite sericite | 3 | | |
| Quartz | 20 | Calcite | | | |
| Varietal (x) | | Magnesium chlorite | | | |
| | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Sphene | 2 | | | | |
| Accessory (y) | | | | | |
| Magnetite | 1 | | | | |
| Ilmenite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. No twinned plagioclase feldspar recognized, largely altered to secondary minerals.
2. Poikilitic, tabular amphiboles, some over 5 mm. in length.
3. Large amounts of cuneiform quartz, some intergrowths with secondary minerals.
4. Late-forming subhedral grains of epidote-clinozoisite in large veinlets filling the fractures. Few flakes white mica up to 1 mm. in length.
5. Sphene patches (2 mm.) forming earlier than amphiboles.
6. Long colorless idiomorphic apatite grains.
7. Coarse phase of sill with quartz blebs up to 2 mm.

Quartz diabase

CLASSIFICATION

G. Hunt

PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Specimen No. SM-14 2900

Locality St. Mary Lake, B.C.

Reference

Date Collected April 1957

Collector G. Hunt, R.A. Burwash

I. FIELD NOTES

Occurrence: Resort Creek Section

Question: 80 ft. below upper contact of "A" sill with Aldridge quartzites

II. HAND SPECIMEN DESCRIPTION

Color: f.s. medium greyish green w.s. rusty

Grain size medium 1-3 mm.

Texture: holocrystalline, phaneritic

Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION

Texture: hypidiomorphic, subophitic, granophyric

Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 55 | Epidote-clinozoisite | 17 | | |
| Plagioclase | 10 | Kaolinite sericite | 13 | | |
| Quartz | 5 | Calcite | | | |
| Varietal (x) | | Magnesium chlorite | | | |
| | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Sphene | 1 | | | | |
| Titaniferous magnetite | | | | | |
| Hematite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Plagioclase feldspars $An_{46}$ are saussuritized.
2. Few small idiomorphic amphibole prisms.
3. Sphene, granophyre in lesser amounts.
4. Subhedral epidote-clinozoisite in large amounts, some completely replacing the amphiboles.
5. Coarse phase of sill.

Quartz diabase

CLASSIFICATION

G. Hunt

PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957

Collector G. Hunt, R.A. Burwash

Specimen No. SM-15 2901

Locality St. Mary Lake, B.C.

Reference

I. FIELD NOTES

Occurrence: Resort Creek Section

Question: 149 ft. below upper contact of "A" sill with the Aldridge quartzites

II. HAND SPECIMEN DESCRIPTION

Color: f.s. medium greyish green w.s. rusty

Grain size medium 1-3 mm.

Texture: holocrystalline, phaneritic

Alteration:

II. MICROSCOPIC STUDY FOR CLASSIFICATION

Texture:

Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 60 | Epidote-clinozoisite | 8 | | |
| Plagioclase | 18 | Kaolinite sericite | 12 | | |
| Quartz | 2 | Calcite | | | |
| Varietal (x) | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Sphene | 1 | | | | |
| Magnetite | | | | | |
| Ilmenite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Sharply twinned plagioclase feldspars, Labradorite $An_{52}$ Oligioclase $An_{29}$.
2. Twinned Amphiboles (average 1 mm.), with subophitic texture.
3. Granophyric intergrowths.

CLASSIFICATION Quartz diabase

PETROGRAPHER G. Hunt

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957
Collector G. Hunt, R.A. Burwash

Specimen No. SM-16 2902
Locality St. Mary Lake, B.C.
Reference

I. FIELD NOTES
Occurrence: Resort Creek Section
Question: near base of "A" sill

II. HAND SPECIMEN DESCRIPTION
Color: f.s. medium greyish green w.s. iron stained
Grain size medium 1-3 mm.
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: subophitic,granophyric
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 60 | Clinozoisite-epidote | 5 | Biotite | 2 |
| Plagioclase | 25 | Kaolinite sericite | | | |
| Quartz | 5 | Calcite | | | |
| | | Magnesium chlorite | | | |
| Varietal (x) | | | | | |
| Sphene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Hematite | 1 | | | | |
| Sphene | | | | | |
| Magnetite | | | | | |

SPECIAL FEATURES:

1. Zoned plagioclase feldspar.
   Carlsbad, Albite and Pericline twinning of the feldspars $An_{48}$.

2. Biotite replacing twinned Amphiboles indicating near base of sill or contact with sediments.
   Few small idiomorphic amphibole prisms.

3. Large amounts granophyric intergrowths.

4. Increase sphene near base of sill.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected Sept. 1957
Collector G. Hunt, R.A. Burwash

Specimen No. SM-20 3075
Locality St. Mary Lake, B.C.
Reference

I. FIELD NOTES
Occurrence: Resort Creek
Question: Sill B

II. HAND SPECIMEN DESCRIPTION
Color: f.s. medium to dark green w.s.
Grain size medium to coarse
Texture: holocrystalline, phaneritic
Alteration:

II. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: subophitic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 55 | Epidote-clinozoisite | 9 | | |
| Plagioclase | 28 | Kaolinite sericite | 5 | | |
| Quartz | 2 | Calcite | | | |
| Varietal (x) | | Magnesium Chlorite | | | |
| | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Sphene | 1 | | | | |
| Magnetite | | | | | |
| Ilmenite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Carlsbad, Albite and Pericline twinning $An_{52}$ and $An_{30}$.
   Minor zoning but mostly sharp, glassy twins of plagioclase feldspar.

2. Light yellow green to dark green pleochroic non twinned amphiboles of Actinolite variety with enclosed chadacrysts of feldspars and quartz.
   Subophitic texture with feldspar laths (up to 2 mm. long) piercing the amphiboles.
   Few small idiomorphic prisms and some Amphiboles are quite fibrous.
   ($2V = 85^{o}$; opt. (-) C to $Z = 18^{o}$).

3. Patches of magnesium chlorite and subhedral epidote-clinozoisite replacing the amphiboles.

Quartz diabase
CLASSIFICATION

G. Hunt
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DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected 1954
Collector R.A. Burwash

Specimen No. EK-1
Locality Kimberley, B.C.
Reference

I. FIELD NOTES
Occurrence: Located east of Sullivan Mine, B.C.
Question:

II. HAND SPECIMEN DESCRIPTION
Color: f.s. medium green w.s.
Grain size medium 1-3 mm.
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: hypidiomorphic, subophitic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 32 | Epidote-clinozoisite | 14 | | |
| Plagioclase | 26 | Kaolinite sericite | 8 | | |
| Quartz | 8 | Calcite | | | |
| Varietal (x) | | Magnesium chlorite | 11 | | |
| | | Biotite | | | |
| | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) Sphene | 1 | | | | |
| Leucoxene | | | | | |
| Titaniferous magnetite | | | | | |
| Pyrrhotite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Many tabular plagioclase feldspar laths are clear, glossy and have sharp Albite twins, composition $An_{55}$, $An_{50}$, $An_{35}$.

2. Poikilitic, twinned and untwinned, Amphibole of the green ferriferous Actinolite variety. In parts, altered to magnesium chlorite, epidote-clinozoisite. Subophitic texture, with the feldspars piercing the amphibole. Actinolite - $2V = 85^{\circ}$; opt. (-) C to Z = $18^{\circ}$.

3. Granophyric intergrowths of quartz and feldspar usually Andesine composition.

4. Patches Titaniferous magnetite altered to Leucoxene.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957
Collector G. Hunt, R.A. Burwash

Specimen No. M-6 2908
Locality Kingsgate, B.C.
Reference

I. FIELD NOTES
Occurrence: Moyie Section
Question: 35 ft. below lower contact of "A" sill with the Aldridge quartzite

II. HAND SPECIMEN DESCRIPTION
Color: f.s. light grey w.s. rusty
Grain size fine to medium
Texture: massive
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: quartzitic, granoblastic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Quartz | 45 | Epidote-clinozoisite | 13 | Biotite | 18 |
| Plagioclase | | Calcite | 4 | Chlorite | 17 |
| Varietal (x) | | Sericite | 1 | | |
| Sphene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Zircon | 1 | | | | |
| Magnetite | | | | | |
| Ilmenite | | | | | |
| Hematite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Trace of plagioclase feldspar with Albite twinning.
2. Quartz with sutured intergrowths, some cuneiform in character.
3. Twinned calcite patches 0.5 mm. in size.
4. Subhedral grains of Epidote.
5. Chlorite replacing Biotite.
6. Long apatite needles.
7. Sphene grains are rounded.

Biotite hornfels
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

M-5

Date Collected April 1957

Collector G. Hunt, R.A. Burwash

Specimen No. 2907

Locality Kingsgate, B.C.

Reference

I. FIELD NOTES

Occurrence: Moyie Section

Question: 5 ft. below lower contact of "A" sill with Aldridge quartzite

II. HAND SPECIMEN DESCRIPTION

Color: f.s. light grey w.s. rusty

Grain size fine to medium

Texture: massive

Alteration:

II. MICROSCOPIC STUDY FOR CLASSIFICATION

Texture: quartzitic, granoblastic

Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Quartz | 45 | | | Hornblende | 3 |
| Plagioclase | | Epidote-clinozoisite | 14 | Biotite | 32 |
| Microcline | | Calcite | | Chlorite | 1 |
| Varietal (x) | | | | | |
| Sphene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Magnetite | 1 | | | | |
| Ilmenite | | | | | |
| Zircon | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Few Albite twinned plagioclase feldspars recognized and minor amounts of microcline with very indistinct grid-iron twins were observed.

2. Strongly, pleochroic hornblendes up to 1.0 mm. in length, some subhedral but not poikilitic or twinned. They are not similar to the amphiboles in the adjacent sill. The hornblende formed after the biotite and in part replaces it. Pleochroism: X - light yellow green, Y - olive green, Z - blue green; Z > Y > X

3. Sutured intergrowths of quartz, some strained.

4. Subhedral grains of epidote and minor carbonate.

5. Sphene grains are rounded.

Hornblende Biotite Hornfels

CLASSIFICATION

G. Hunt

PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957
Collector G. Hunt, R.A. Burwash

Specimen No. M-4 2906
Locality Kingsgate, B.C.
Reference

I. FIELD NOTES
Occurrence: Moyie Section
Question: near the lower contact of "A" sill with the Aldridge quartzite

II. HAND SPECIMEN DESCRIPTION
Color: f.s. light grey w.s. rusty
Grain size fine to medium
Texture: massive, baked
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: quartzitic, granoblastic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| | | Epidote-clinozoisite | 30 | | |
| Quartz | 30 | Kaolinite sericite | 13 | | |
| | | Chlorite | 20 | | |
| | | Calcite | 5 | | |
| Varietal (x) | | Biotite | 2 | | |
| | | Leucoxene | | | |
| | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Sphene | 1 | | | | |
| Magnetite | | | | | |
| Ilmenite | | | | | |
| Hematite | | | | | |

SPECIAL FEATURES:

1. Angular quartz grains up to 0.5 mm. size show undulatory extinction and sutured quartzitic boundaries between some quartz grains.

2. Blebs of twinned calcite average 0.3 mm. in size, calcite present as veinlets as well as bonding material.

3. Chlorite replacing the biotite in part.

4. Very minor amounts of feldspar, largely replaced by secondary minerals.

Hornfels
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957
Collector G. Hunt, R.A. Burwash

Specimen No. M-3 2905
Locality Kingsgate, B.C.
Reference

I. FIELD NOTES
Occurrence: Moyie Section
Question: near lower contact of "A" sill with Aldridge quartzite

II. HAND SPECIMEN DESCRIPTION
Color: f.s. medium green w.s.
Grain size medium
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: subophitic, granophyric
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 50 | Epidote-clinozoisite | 7 | Biotite | 1 |
| Plagioclase | 9 | Kaolinite sericite | 11 | Chlorite | 12 |
| Quartz | 8 | Magnesium chlorite | | | |
| Varietal (x) | | Calcite | | | |
| Sphene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Magnetite | 1 | | | | |
| Ilmenite | | | | | |

SPECIAL FEATURES:

1. Plagioclase feldspars $An_{52}$ are highly altered.
2. Twinned, poikilitic, curved, green amphibole $2V = 80^{o}$; optically (-); C to Z = 18
3. Large amounts of granophyre showing feldspar acting as host.
4. Biotite present indicates contact of sill with sediments.
5. Two different chlorite alteration products but mainly iron-rich variety with anomalous interference colors.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected April 1957

Collector G. Hunt, R.A. Burwash

Specimen No. M-2 2904

Locality Kingsgate, B.C.

Reference

I. FIELD NOTES

Occurrence: Moyie Section

Question: 10 ft. above lower contact of "A" sill with Aldridge quartzites

II. HAND SPECIMEN DESCRIPTION

Color: f.s. medium green w.s.

Grain size medium 1-3 mm.

Texture: holocrystalline, phaneritic

Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION

Texture: subophitic, granophyric

Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 50 | Epidote-clinozosite | 5 | | |
| Plagioclase | 10 | Kaolinite sericite | 25 | | |
| Quartz | 7 | Chlorite | | | |
| Varietal (x) | | Calcite | 5 | | |
| Sphene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Magnetite | 1 | | | | |
| Pyrrhotite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Plagioclase feldspars are zoned ranging from $An_{54}$ to $An_{30}$ but considerable alteration to secondary minerals has taken place.

2. Twinned, poikilitic, fibrous green amphibole.

3. Cuneiform granophyre texture.

4. Calcite blebs 1 mm. size and veinlets.

Quartz diabase

CLASSIFICATION

G. Hunt

PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

M-1

Date Collected April 1957
Collector G. Hunt, R.A. Burwash

Specimen No. 2903
Locality Kingsgate, B.C.
Reference

I. FIELD NOTES
Occurrence: Moyie Section
Question: 30 ft. above lower contact of "A" sill with Aldridge quartzite

II. HAND SPECIMEN DESCRIPTION
Color: f.s. medium green w.s.
Grain size medium grained
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: subophitic, granophyric
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Actinolite | 60 | Epidote-clinozoisite | 3 | | |
| Plagioclase | 10 | Kaolinite-sericite | 20 | | |
| Quartz | 2 | Calcite | | | |
| Varietal (x) | | Chlorite | 2 | | |
| Sphene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Accessory (y) | | | | | |
| Magnetite | 1 | | | | |
| Ilmenite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Plagioclase feldspars are highly altered to secondary minerals. Few tabular laths with Albite twinning having composition $An_{42}$.

2. Green amphibole with relict subophitic texture.

3. Minor granophyre.

4. The sample is taken near the upper contact of "A" sill.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

**UNIVERSITY OF ALBERTA**

**DEPARTMENT OF GEOLOGY AND MINERALOGY**

# PETROGRAPHIC DESCRIPTION

Date Collected Sept. 1957
Collector G. Hunt

Specimen No. W-10 3068
Locality Reference Waterton Park, Alta.

I. FIELD NOTES
Occurrence: Blakiston Brook Section
Question: 5 ft. below upper contact of sill with Grinnel formation

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s. iron stained
Grain size medium
Texture: holocrystalline, phaneritic
Alteration: saussuritized

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: diabasic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 20 | Kaolinite sericite | 17 | Chlorite | 14 |
| Plagioclase | 25 | Epidote-clinozoisite | 3 | Magnetite | 6 |
| Quartz | 5 | Calcite | | | |
| Varietal (x) | | | | | |
| Titaniferous magnetite | 5 | | | | |
| Leucoxene | 3 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Sphene | 1 | | | | |
| Accessory (y) | | | | | |
| Chlor-apatite | 1 | | | | |
| Pyrrhotite | | | | | |

SPECIAL FEATURES:

1. Small plagioclase feldspar $An_{32}$ and corroded pyroxene with diabasic texture.

2. Skeletal titaniferous magnetite forming reaction rims with chlorite. Primary magnetite altered to leucoxene.

3. Less concentration of sphene at top of sill than bottom.

4. Grain size of essential minerals average 1 mm. (smaller than near center of sill).

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

W-9

Date Collected Sept. 1957
Collector G. Hunt

Specimen No. 3067
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Blakiston Brook Section
Question: 20 ft. below upper contact of sill with Grinnel formation

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s. hematite stained
Grain size medium
Texture: holocrystalline, phaneritic
Alteration: saussuritization

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: diabasic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 15 | Calcite | 9 | Chlorite | 33 |
| Plagioclase | 18 | Kaolinite-sericite | 6 | Magnetite | 5 |
| Quartz | 2 | Epidote-clinozoisite | | | |
| Varietal (x) | | | | | |
| Titaniferous magnetite | 5 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Leucoxene | 5 | | | | |
| Sphene | 2 | | | | |
| Accessory (y) | | | | | |
| Chlor-apatite | 1 | | | | |
| Pyrrhotite | | | | | |
| Hematite | | | | | |

SPECIAL FEATURES:

1. Saussuritized feldspars $An_{28}$ and pyroxene with diabasic texture.
2. Blebs, patches and veinlets of calcite.
3. Skeletal magnetite and chlorite forming Kelyphitic rims.
4. Long acicular laths leucoxene up to 3 mm. in length.
5. The calcite veins are associated with secondary quartz and the smaller plagioclase laths. Some of the quartz surrounds the chlorite.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected Sept. 1957
Collector G. Hunt

Specimen No. W-8 3066
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Blakiston Brook Section
Question: 30 ft. below upper contact of sill with Grinnel formation

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s. hematite stain
Grain size medium
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: diabasic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 17 | Epidote-clinozoisite | 13 | Chlorite | 20 |
| Plagioclase | 25 | Kaolinite sericite | | Magnetite | 5 |
| Quartz | 5 | Calcite | | | |
| Varietal (x) | | | | | |
| Titaniferous magnetite | 8 | | | | |
| Leucoxene | 7 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Sphene | 2 | | | | |
| Accessory (y) | | | | | |
| Chlor-apatite | 1 | | | | |
| Pyrrhotite | | | | | |

SPECIAL FEATURES:

1. Plagioclase laths are highly saussuritized but smaller laths show $An_{28}$.

2. Red brown Augite up to 3 mm. in length has characteristic diabasic texture. Some Augite crystals are twinned.

3. Subhedral granular grains of epidote and long needles of apatite.

4. Granophyric intergrowths of quartz and feldspar (2%).

5. Large skeletal and spear-shaped grains of titaniferous magnetite are altered to leucoxene. Metamorphic magnetite associated with chlorite and late forming quartz shows corona structures in which the chlorite core has replaced a mineral (usually augite) and is in turn surrounded by a magnetite rim.

6. Coarse phase of sill.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected Sept. 1957
Collector G. Hunt

Specimen No. W-7 3065
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Blakiston Brook
Question: 15 ft. above lower contact of sill with Grinnel formation

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s. hematite stain
Grain size medium
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: diabasic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 18 | Epidote-clinozoisite | 15 | Chlorite | 17 |
| Plagioclase | 25 | Kaolinite sericite | | Magnetite | 5 |
| Quartz | 5 | Calcite | | | |
| Varietal (x) | | | | | |
| Titaniferous Magnetite | 6 | | | | |
| Leucoxene | 5 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Sphene | 2 | | | | |
| Accessory (y) | | | | | |
| Chlor-apatite | 1 | | | | |
| Pyrrhotite | | | | | |

SPECIAL FEATURES:

1. The large plagioclase laths are highly saussuritized and smaller laths show $An_{32}$. Large titaniferous magnetite grains are skeletal and altered to leucoxene.

2. Some of the reddish brown pyroxene exhibits schiller and diabasic textures.

3. Increase quartz but lesser amounts of intersertal secondary minerals such as epidote, calcite, etc.

4. Magnetite forms skeletal rims around chlorite which has replaced some other mineral.

5. Decrease amounts of leucoxene and sphene.

6. Coarse phase of sill.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected Sept. 1957
Collector G. Hunt

Specimen No. W-6 3064
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Blakiston Brook Section
Question: 10 ft. above lower contact of sill with Grinnel formation

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s. hematite stain
Grain size medium 1 mm.
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: diabasic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 20 | Kaolinite sericite | 25 | Chlorite | 19 |
| Plagioclase | 10 | Epidote clinozoisite | | Magnetite | 5 |
| Quartz | 2 | Calcite | 2 | | |
| Varietal (x) | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Titaniferous Magnetite | 5 | | | | |
| Leucoxene | 5 | | | | |
| Sphene | 5 | | | | |
| Accessory (y) | | | | | |
| Chlor-apatite | 1 | | | | |
| Pyrrhotite | | | | | |

SPECIAL FEATURES:

1. Larger, plagioclase feldspar laths are highly saussuritized and smaller grains have $An_{38}$.

2. Corroded, red brown, pyroxene and feldspars are interwoven in a diabasic texture.

3. Blebs, patches and veinlets of calcite.

4. Trace of granophyric intergrowths.

5. Skeletal crystals of magnetite associated with chlorite and primary titaniferous magnetite.

6. Rock is badly fractured and iron stained.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected Sept. 1957
Collector G. Hunt

Specimen No. W-5 3063
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Blakiston Brook Section
Question: 5 ft. above lower contact of sill with Grinnel formation

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s. hematite stain
Grain size medium 1-3 mm.
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: hypidiomorphic, diabasic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 15 | Epidote-clinozoisite | 28 | Chlorite | 15 |
| Plagioclase | 10 | Kaolinite sericite | | Magnetite | 10 |
| Quartz | 2 | Calcite | | | |
| Varietal (x) | | | | | |
| Titaniferous magnetite | 10 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Leucoxene | 5 | | | | |
| Sphene | 4 | | | | |
| Accessory (y) | | | | | |
| Rutile | | | | | |
| Chlor-apatite | 1 | | | | |
| Hematite | | | | | |

SPECIAL FEATURES:

1. Larger, plagioclase feldspar laths are highly altered but smaller late-forming grains have $An_{32}$.

2. Corroded, tabular, reddish brown Titaniferous Augite with diabasic texture. Augite - $2V = 62^{o}$; opt. (+); C to Z = $45^{o}$.

3. Intergranular iron ores and intersertal secondary minerals form Kelyphitic reaction rims - skeletal crystals of magnetite enclosing chlorite. Primary large needle-like and octahedral titaniferous magnetite is partly altered to leucoxene.

4. Long chlor-apatite needles up to 0.2 mm.

5. Abnormal amount of leucoxene and sphene.

6. Badly fractured rock with iron oxide filling.

Quartz diabase

CLASSIFICATION

G. Hunt

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# PETROGRAPHIC DESCRIPTION

Date Collected 1955
Collector T. Patching

Specimen No. 3176
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Lake Alderson Section
Question: Basal contact of sill with Siyeh limestone

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s.
Grain size fine to cryptocrystalline
Texture: holocrystalline, aphanitic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: porphyritic, kelyphitic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential Phenocrysts | | Alteration products (z) | | | |
| Augite | 12 | Reaction rims | 9 | | |
| Plagioclase | 3 | Ilmenite | | | |
| Quartz | | Leucoxene | | | |
| Varietal (x) | | Chlorite | | | |
| Pyrrhotite | 7 | GROUNDMASS ~~OR CEMENT~~ | | MINERALIZATION | |
| | | Aphanitic groundmass | 69 | | |
| Accessory (y) | | | | | |

SPECIAL FEATURES:

1. Small, tabular plagioclase lineated parallel to the contact of the sill with the sediments. The glassy, clear, fresh laths have $An_{54}$, Labradorite.

2. Some red brown Augite phenocrysts are twinned, euhedral and corroded.

3. Very well developed Kelyphitic reaction rims - chlorite, ilmenite and limonite.

4. Fine grained chilled sill at contact.

Fine grained quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected 1955
Collector T. Patching

Specimen No. 3177
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Lake Alderson Section
Question: 5 ft. above lower contact of sill with the Siyeh limestone

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s.
Grain size fine
Texture: holocrystalline, aphanitic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: hypidiomorphic, granophyric
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 30 | | | | |
| Brown & Green hornblende | 8 | Calcite | 25 | Chlorite | 15 |
| Plagioclase | 9 | Epidote-clinozoisite | | Magnetite | 4 |
| Quartz | 3 | Kaolinite-sericite | | | |
| Varietal (x) | | | | | |
| Titaniferous magnetite | 5 | | | | |
| Leucoxene | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Sphene | 2 | | | | |
| Accessory (y) | | | | | |
| Pyrrhotite | 1 | | | | |
| Hematite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Very few twinned feldspars, largely altered to calcite, sericite.

2. Cores of red brown, non pleochroic titaniferous Augite largely altered to secondary minerals.

3. Subhedral to euhedral brown strongly pleochroic hornblende, some show twinning.

4. Intersertal secondary minerals calcite and epidote in large amounts. Iron rich chlorite and skeletal magnetite.

5. Minor amount of granophyre.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected 1955
Collector T. Patching

Specimen No. 3178
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Lake Alderson Section
Question: Coarse phase in centre of sill

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s.
Grain size medium size 1 mm.
Texture: holocrystalline, phaneritic
Alteration: saussuritization

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: subophitic, granophyric
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 25 | Calcite | 25 | Chlorite | 13 |
| Brown & Green hornblende | 4 | Epidote-clinozoisite | | Magnetite | 4 |
| Plagioclase | 13 | Kaolinite-sericite | | | |
| Quartz | 7 | | | | |
| Varietal (x) | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Titaniferous magnetite | 5 | | | | |
| Leucoxene | 4 | | | | |
| Sphene | 1 | | | | |
| Accessory (y) | | | | | |
| Pyrrhotite | 1 | | | | |
| Hematite | | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Plagioclase feldspars $An_{34}$ are highly saussuritized (up to 1 mm. in length).

2. Corona structures of red brown Augite surrounded by brown and green subhedral hornblende. Subophitic texture with feldspar.

3. Granophyric intergrowths of quartz and feldspar in cuneiform textures.

4. Intergranular skeletal titaniferous magnetite largely altered to leucoxene.

5. Large amounts of calcite in blebs and radial structures.

6. Skeletal magnetite with aggregate iron rich chlorite apparently last to form.

Quartz diabase
CLASSIFICATION

G. Hunt
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UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected 1955
Collector T. Patching

Specimen No. 3179
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Lake Alderson Section
Question: 5 ft. below upper contact of sill with Siyeh limestone

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s.
Grain size medium grained 1 mm.
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: subophitic, granophyric
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 21 | | | | |
| Brown & Green hornblende | 8 | Epidote-clinozoisite | 16 | Chlorite | 15 |
| Plagioclase | 10 | Calcite | 14 | Magnetite | 3 |
| Quartz | 5 | Kaolinite sericite | | | |
| Varietal (x) | | | | | |
| Titaniferous magnetite | 4 | | | | |
| Leucoxene | 4 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Sphene | 1 | | | | |
| Accessory (y) | | | | | |
| Pyrrhotite | 1 | | | | |
| Apatite | | | | | |

SPECIAL FEATURES:

1. Plagioclase feldspars are highly saussuritized to secondary minerals but show subophitic texture.

2. Corona cores of red brown Augite up to 1 mm. long uralitized to subhedral hornblende, some twinned. Brown hornblende - pleochroic; $2V = 72^{o}$; opt. (-); C to Z = $15^{o}$.

3. Blebs, radial patches of calcite (1 mm), some twinned.

4. Skeletal magnetite (altered to leucoxene) and chlorite form Kelyphitic reaction rims.

5. Intersertal grains of epidote up to 1 mm. in length. Iron rich chlorite replaces the mafics.

6. Long chlor-apatite needles 0.5 mm.

7. Patches of quartz (2 mm.) and some cuneiform intergrowths.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA

DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected 1955
Collector T. Patching

Specimen No. 3180
Locality Waterton Park, Alta.
Reference

I. FIELD NOTES
Occurrence: Lake Alderson Section
Question: upper chilled phase

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s.
Grain size fine grained
Texture: holocrystalline, aphanitic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: porphyritic
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 33 | | | Chlorite | 6 |
| Plagioclase | 10 | Epidote-clinozoisite | 20 | Magnetite | 10 |
| Quartz | 5 | Kaolinite-sericite | | | |
| Varietal (x) | | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Titaniferous magnetite | 15 | | | | |
| Leucoxene | . | | | | |
| Accessory (y) | | | | | |
| Pyrrhotite | 1 | | | | |
| Sphene | | | | | |

SPECIAL FEATURES:

1. Plagioclase feldspars are saussuritized.

2. Corroded red brown Augite phenocrysts average 0.2 mm. in groundmass of Augite, feldspars, acicular magnetite, chlorite and intersertal secondary minerals.

3. Small titaniferous magnetite needles in very large amounts with minor leucoxene.

Fine grained quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

UNIVERSITY OF ALBERTA
DEPARTMENT OF GEOLOGY AND MINERALOGY

# PETROGRAPHIC DESCRIPTION

Date Collected 1957
Collector R.E. Folinsbee

Specimen No. 2999
Locality Glacier Park, Mont.
Reference

I. FIELD NOTES
Occurrence: Located in the parking lot at Logan Pass, Montana
Question: Southward extension of Lake Alderson sill

II. HAND SPECIMEN DESCRIPTION
Color: f.s. dark green w.s. grey brown
Grain size medium to coarse
Texture: holocrystalline, phaneritic
Alteration:

III. MICROSCOPIC STUDY FOR CLASSIFICATION
Texture: subophitic, granophyric
Structure: original secondary

| PRIMARY MINERALS | % | SECONDARY MINERALS | % | METAMORPHIC MINERALS | % |
|---|---|---|---|---|---|
| Essential | | Alteration products (z) | | | |
| Titaniferous Augite | 8 | | | | |
| Brown & Green hornblende | 20 | Calcite | 7 | Chlorite | 20 |
| Plagioclase | 15 | Epidote-clinozoisite | 7 | Magnetite | 2 |
| Quartz | 10 | Kaolinite-sericite | | | |
| Varietal (x) | | | | | |
| Titaniferous magnetite | 2 | GROUNDMASS OR CEMENT | | MINERALIZATION | |
| Leucoxene | 5 | | | | |
| Sphene | 2 | | | | |
| Accessory (y) | | | | | |
| Apatite | 1 | | | | |
| Pyrrhotite | | | | | |
| Ilmenite | | | | | |

SPECIAL FEATURES:
1. Most plagioclase feldspars are saussuritized but some have glassy Albite twins $An_{35}$.

2. Cores of reddish brown Augite uralitized to green, pleochroic hornblende.
Augite shows subophitic textures with the long feldspar laths (up to 3 mm.).
Brown hornblende - pleochroic, $2V = 70^{\circ}$; optically (-); C to Z = $15^{\circ}$.

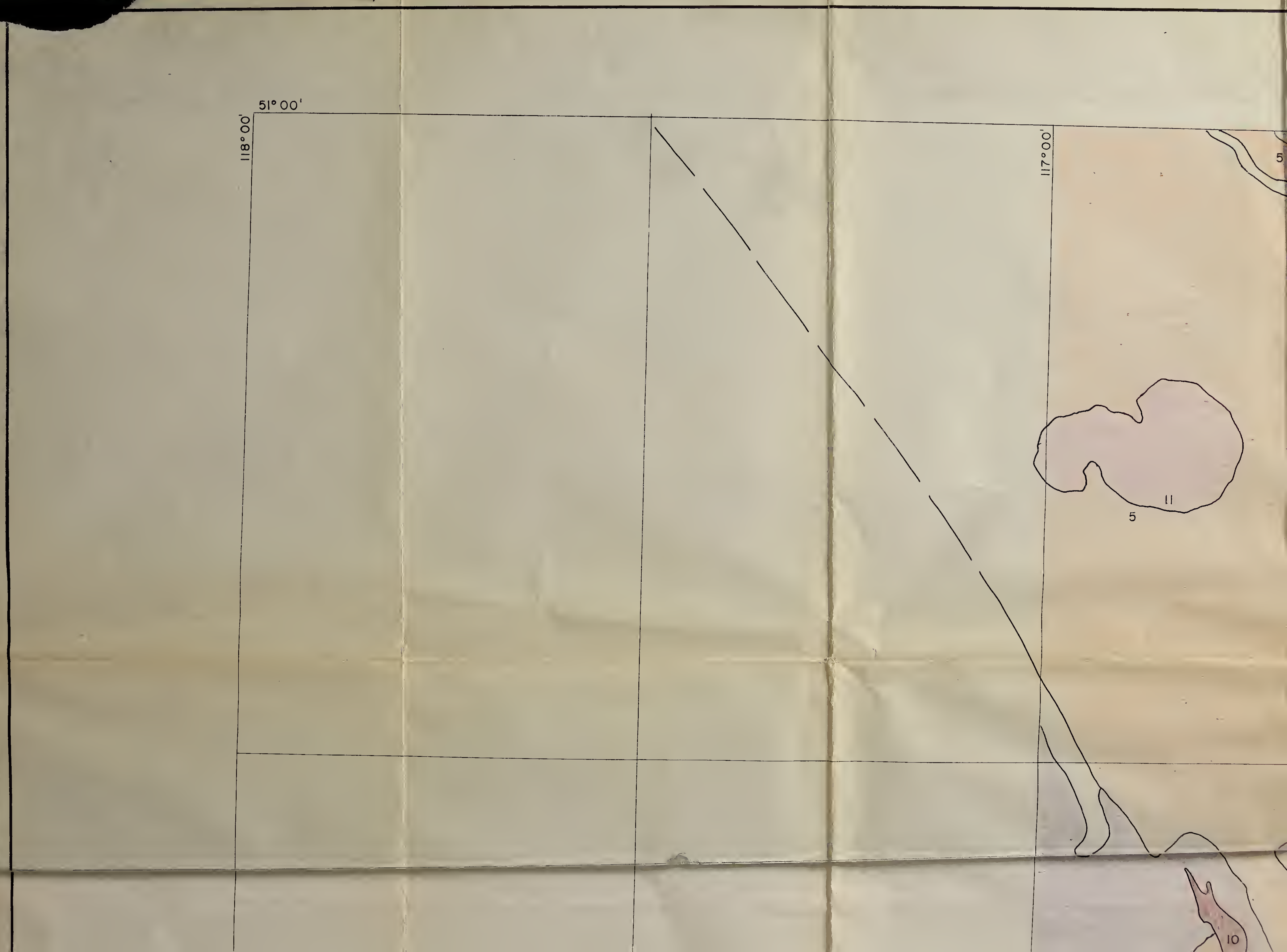
3. Alteration - Augite to green hornblende; brown hornblende to green hornblende.

4. Subhedral grains of intersertal epidote (up to 2 mm.).
Iron rich chlorite replacing the mafics.
5. Skeletal and octahedral titaniferous magnetite altered to leucoxene.
6. Intergrowths of quartz and feldspar in cuneiform structures.
7. Quartz grains up to 1 mm.
8. Acicular apatite needles.

Quartz diabase
CLASSIFICATION

G. Hunt
PETROGRAPHER

FORM 1909



51° 00'
118° 00'
117° 00'
5
11
5
10


117°00'
116°00'
KOOTENAY RIVER
COLUMBIA RIVER
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7
11
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8
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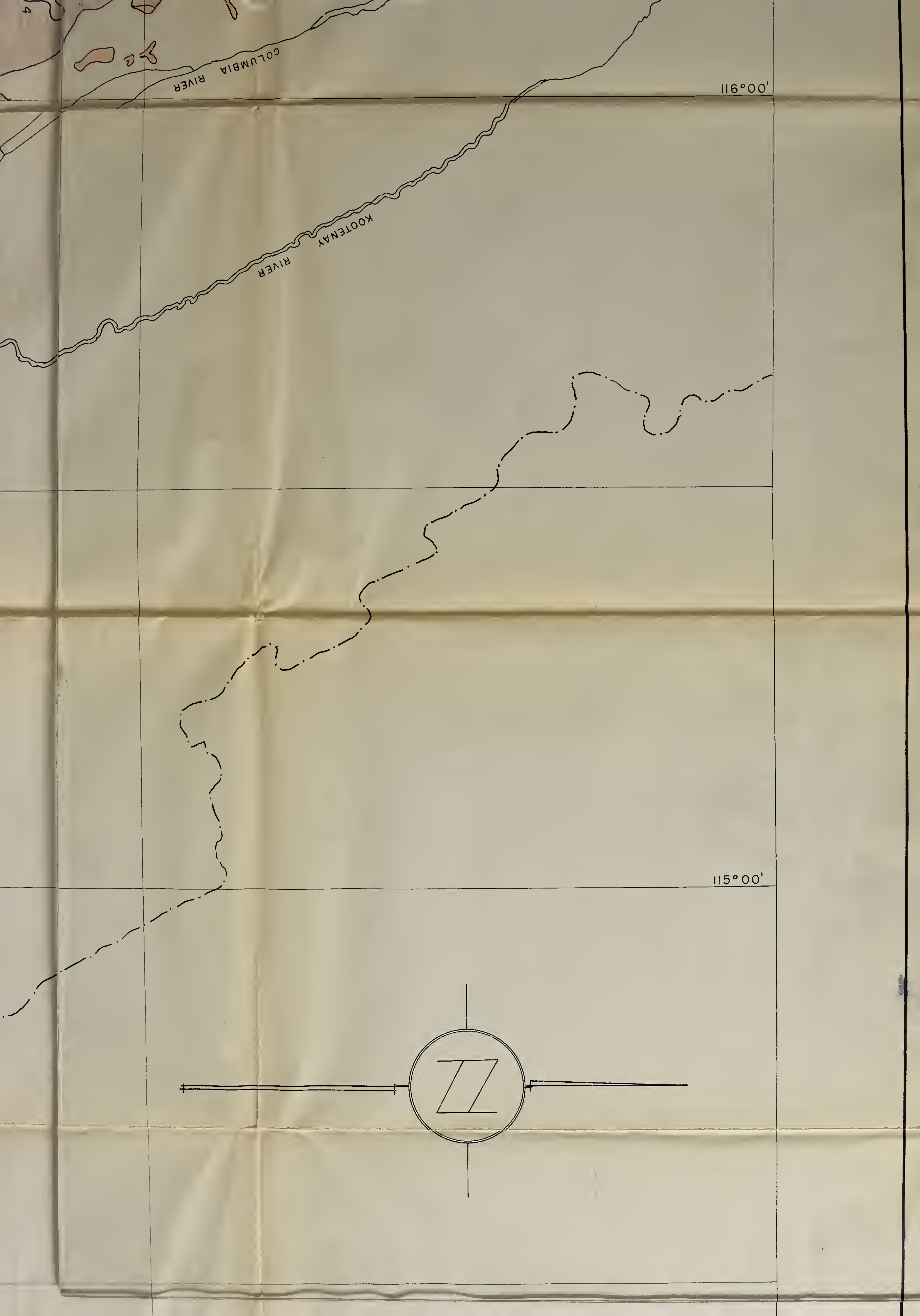
4


116°00'
115°00'
KOOTENAY RIVER
COLUMBIA RIVER
N
4

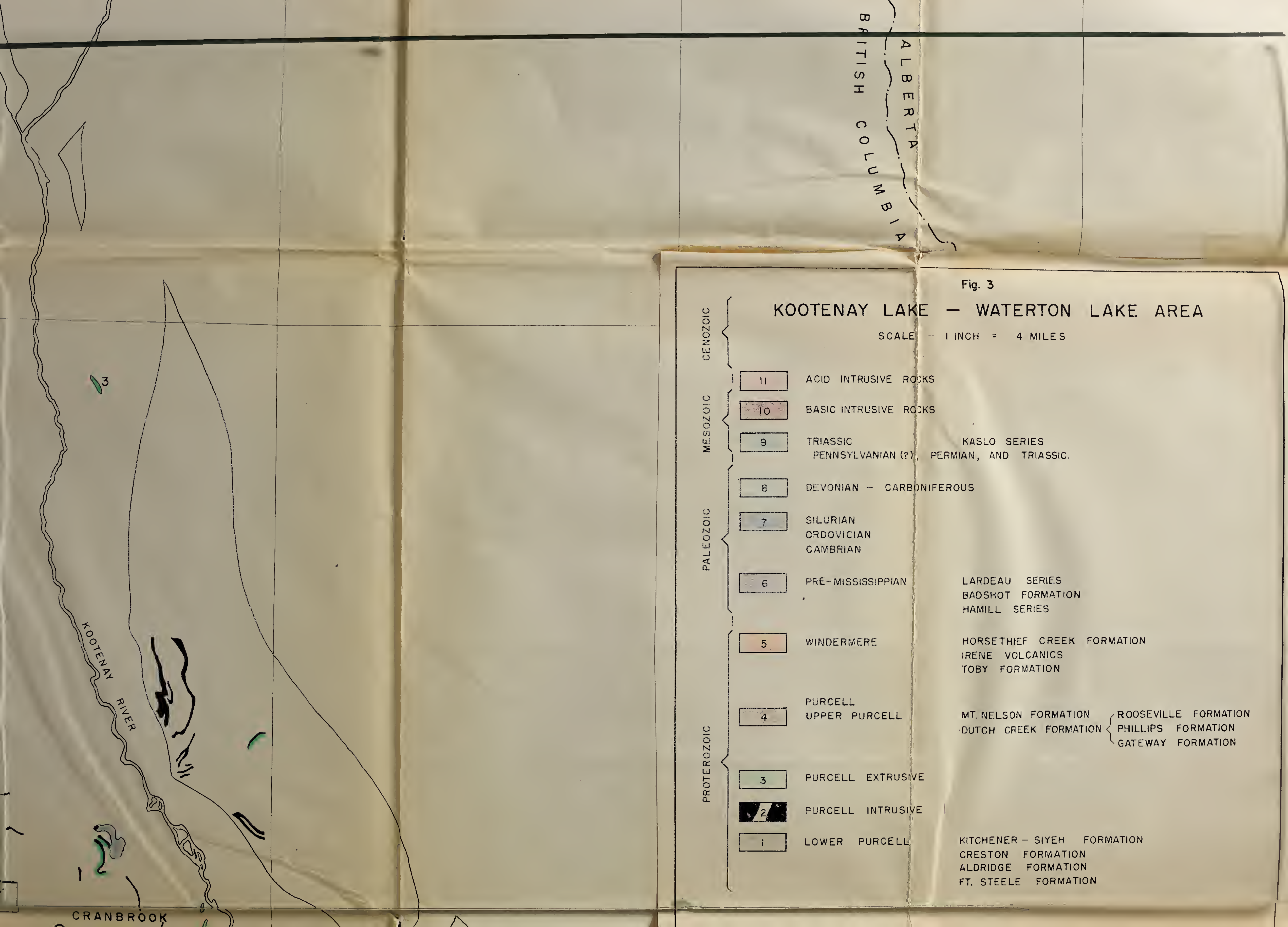
51°00'

114°00'

113°00'


50°00'
SLOCAN LAKE
6
9
6
9 6
11
11 9
6
11
6

KIMBERLY FAULT
SULLIVAN INTRUSIVE
KIMBERLY
ST. MARY SILLS
ST. MARY FAULT
HALL LAKE FAULT
KOOTENAY RIVER
KE
KOOT



ALBERTA
BRITISH COLUMBIA
KOOTENAY RIVER
CRANBROOK
3
Fig. 3
KOOTENAY LAKE — WATERTON LAKE AREA
SCALE - 1 INCH = 4 MILES
CENOZOIC
MESOZOIC
PALEOZOIC
PROTEROZOIC
11 ACID INTRUSIVE ROCKS
10 BASIC INTRUSIVE ROCKS
9 TRIASSIC KASLO SERIES
PENNSYLVANIAN (?), PERMIAN, AND TRIASSIC.
8 DEVONIAN - CARBONIFEROUS
7 SILURIAN
ORDOVICIAN
CAMBRIAN
6 PRE-MISSISSIPPIAN LARDEAU SERIES
BADSHOT FORMATION
HAMILL SERIES
5 WINDERMERE HORSETHIEF CREEK FORMATION
IRENE VOLCANICS
TOBY FORMATION
4 PURCELL
UPPER PURCELL MT. NELSON FORMATION
DUTCH CREEK FORMATION
ROOSEVILLE FORMATION
PHILLIPS FORMATION
GATEWAY FORMATION
3 PURCELL EXTRUSIVE
2 PURCELL INTRUSIVE
1 LOWER PURCELL KITCHENER - SIYEH FORMATION
CRESTON FORMATION
ALDRIDGE FORMATION
FT. STEELE FORMATION

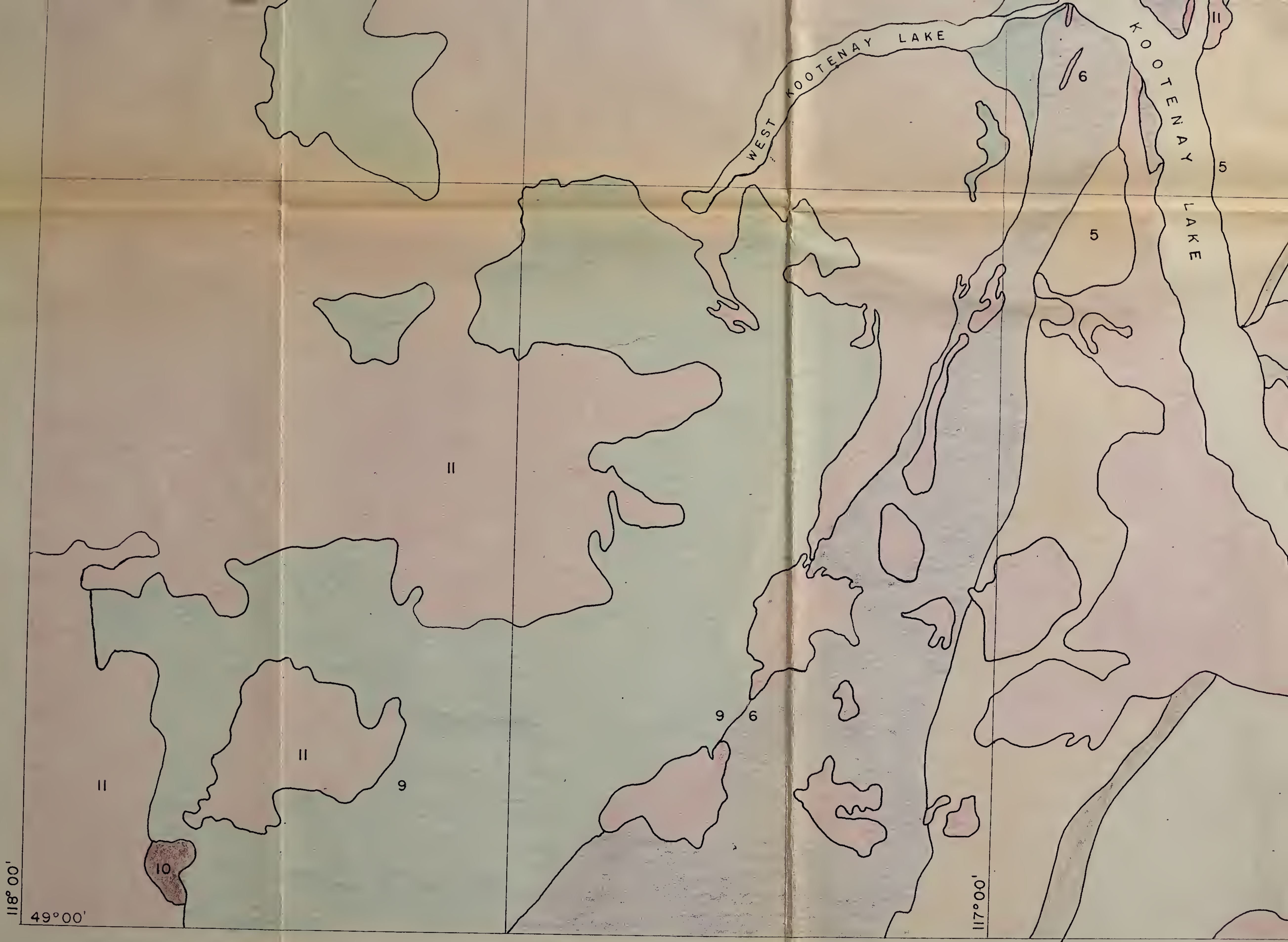
AREA

50°00'

ON

OOSEVILLE FORMATION
ILLIPS FORMATION
ATEWAY FORMATION

ION


WEST KOOTENAY LAKE
KOOTENAY LAKE
118°00'
49°00'
117°00'
11
11
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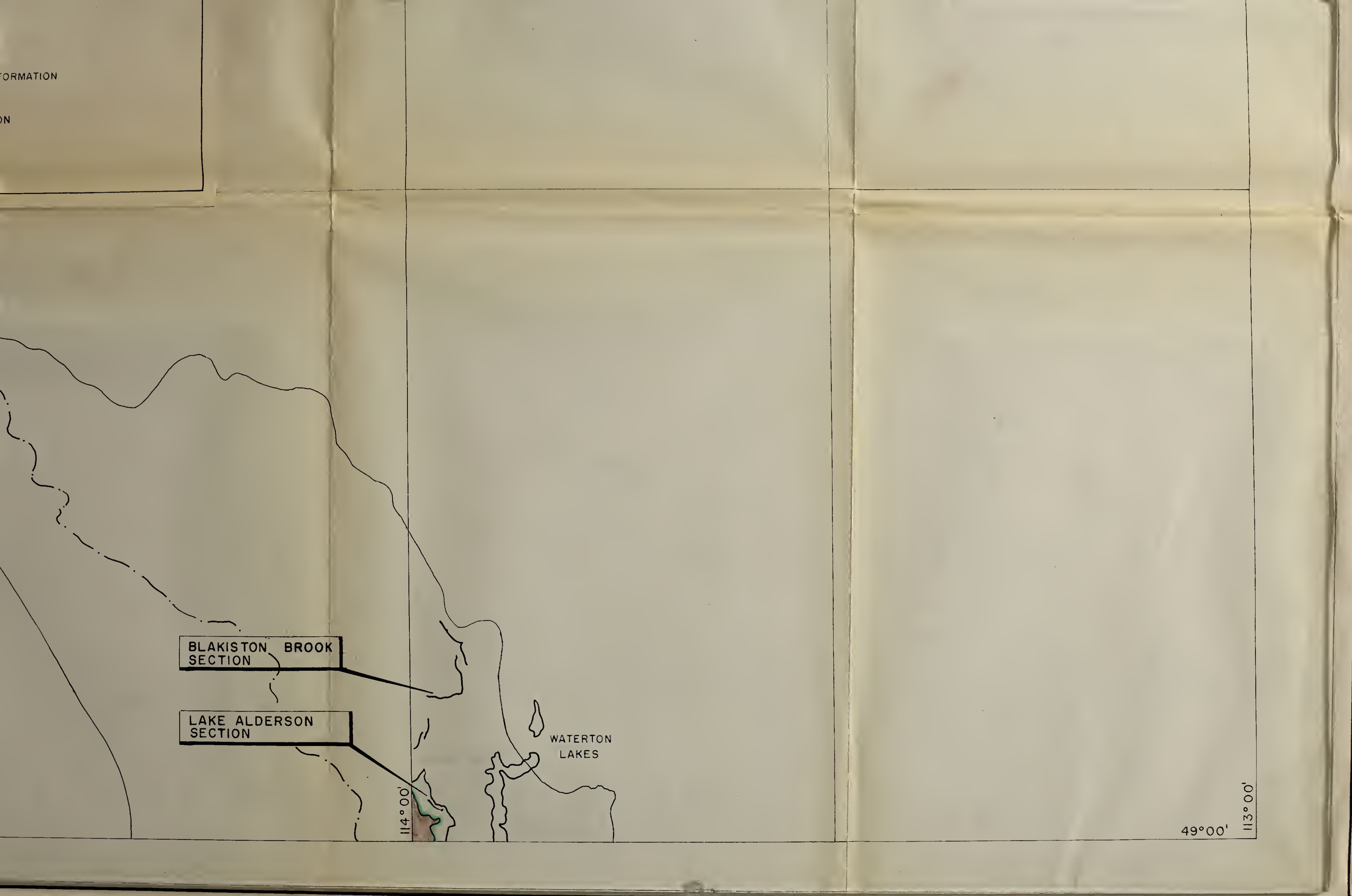
11
10
9
9
6
6
5
5
5


ENAY LAKE
KOOTENAY LAKE
ST. MARY FAULT
RESORT CREEK SECTION
CRANBROOK
MOYIE FAULT
CRESTON
MOYIE SILLS
MOYIE SECTION
KINGSGATE
117°00'
116°00'

PURCELL INTRUSIVE
LOWER PURCELL
KITCHENER – SIYEH FORMATION
CRESTON FORMATION
ALDRIDGE FORMATION
FT. STEELE FORMATION
CRANBROOK
115° 00"


BLAKISTON BROOK SECTION
LAKE ALDERSON SECTION
WATERTON LAKES
114°00'
113°00'
49°00'